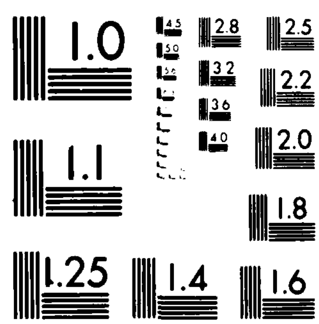
AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

UNCLASSIFIED NRL-MR-4601 NL

1 OF 8
AD
A111931

1193



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

ADA111931

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NRL MEMORANDUM REPORT 4601	2. GOVT ACCESSION NO. AD-A114931
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Handbook of Pressure-Proof Connector and Cable Harness Design for Sonar Systems	5. TYPE OF REPORT & PERIOD COVERED: Final report on completed contract.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): R. F. Haworth*	8. CONTRACT OR GRANT NUMBER(s): N61339-80-C-0021
9. PERFORMING ORGANIZATION NAME AND ADDRESS: General Dynamics Corporation, Electric Boat Division, Eastern Point Rd., Groton, CT 06340	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: PE-64503, S0219-AS, (59)-0584-02
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Research Laboratory, Underwater Sound Reference Detachment, PO Box 8337, Orlando, FL 32856	12. REPORT DATE
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Naval Sea Systems Command (SEA63X5), Washington, DC 20362	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*This handbook was written under USRD contract to Electric Boat Div. of General Dynamics Corp. and sponsored by the Sonar Transducer Reliability Improvement Program (STRIP).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cables
Cable assemblies
Cable harnesses
Connectors
Electrical cables
Electrical connectors
Sonar equipment
Underwater cables
Underwater connectors

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Navy personnel and agencies involved in the design and selection of pressure-proof sonar system electrical connectors, cable harnesses, and hull penetrators are noted. Military specifications, drawings, and standards for these components are listed. Factors are listed and discussed for the proper design of pressure-proof electrical connectors, cable harnesses, and hull penetrators. Procedures are provided for wiring and molding connectors to cables using polyurethane, neoprene, butyl, and ethylene propylene rubbers as well as (cont'd. on reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (cont'd.) polyethylene plastic. Outboard cable splicing and repair methods are detailed. Outboard cable harness test requirements are listed as well as cable harness handling, installation, replacement, and test methods. Quality control considerations and a typical failure mode and effects analysis are provided for pressure-proof connectors and cable harnesses. A listing of suppliers and personnel involved in pressure-proof cable, cable harnesses, connector, and hull penetrator design and use is also provided.

CONTENTS

FOREWORD

Most of the data included in this handbook have been made available due to the foresight, persistance, management, and engineering efforts of Mr. Frank Richardson, NAVSEA, now retired; and Mr. John Regan, NAVSEA Code 5433.

Through their efforts, pressure-proof electrical connectors, cable harnesses, and submarine hull penetrators have been designed and qualified to meet Navy military submarine requirements.

They have also been responsible for similar designs in use by the Navy on deep submergence vehicles (DSV's) and platforms including DOLPHIN, NR-1, SEA CLIFF, TURTLE, TRIESTE, and Deep Submergence Rescue Vehicle (DSRV).

INTRODUCTION

The Handbook of Pressure-Proof Connectors and Cable Harnesses Design for Hydrophones and Transducers has been prepared as a guide for designers, engineers, and operating personnel concerned with Sonar System design for submarines, surface ships, and bottom-mounted arrays.

It is a compilation of engineering data and criteria obtained from published sources and consultations with electrical connector and cable manufacturers, users, and surface-ship and submarine operating personnel.

This handbook has been prepared for the U.S. Navy under the sponsorship of the Sonar Transducer Reliability Improvement Program (STRIP). The work was conducted under the technical direction of the Naval Research Laboratory, Underwater Sound Reference Detachment (NRL-USRD), Orlando, Florida. Mr. Raymond Haworth of the Electric Boat Division of General Dynamics Corp. has prepared this document under contract N61339-80-C-0021. The Program Manager for the STRIP, sponsored by the Naval Sea Systems Command (NAVSEA) SEA63X5, is Dr. R. W. Timme, NRL-USRD. Mr. G. D. Hugus, NRL-USRD, has provided technical direction for preparation of this handbook.

This handbook is designed to be periodically revised to reflect new information on electrical connectors, cable harnesses, manufacturing techniques, installation and repair methods, and

general technology gained via the STRIP program. Maintenance and expansion of the handbook is the responsibility of NAVSEA utilizing the NRL-USRD as Technical Agent.

Section 1 lists cognizant NAVSEA personnel responsible for Sonar System designs as well as outboard cables, connectors, and hull penetrators used on sonar systems. Pertinent Navy specifications, standards, drawings, and handbooks covering these designs are noted in this section.

Section 2 identifies NAVSEA approved pressure-proof electrical connectors used on submarine, surface ship, and DSV sonar systems. Connector details of construction are provided in this section.

Section 3 lists outboard cables that have been approved for use on surface ship, submarine, and DSV sonar systems. Cable details of construction are noted in this section.

Section 4 notes the Navy approved documents that are used to fabricate outboard sonar system cable harnesses.

Section 5 identifies approved pressure hull penetrators used on submarines, surface ships, and DSV sonar systems. Details of construction of hull penetrators are provided in this section.

Section 6 lists and discusses the factors involved in the design of pressure-proof outboard electrical connectors.

Section 7 depicts recommended attachment methods for sealing

and mounting pressure-proof connector receptacles to sonar systems component enclosures.

Section 8 lists and discusses factors involved in the design of outboard sonar system cables.

Section 9 lists and discusses factors that must be considered in the design and fabrication of outboard sonar system cable harnesses.

Section 10 provides pressure-proof connector and cable gland wiring and molding fabrication procedures used on Navy sonar systems. Procedures for molding with polyurethane, neoprene, butyl, and ethylene propylene rubbers are provided as well as polyethylene molding and epoxy potting.

Section 11 lists and discusses various cable splice and repair methods that have been used by the Navy to service outboard sonar systems.

Section 12 lists recommended sequential tests and procedures for qualification and quality conformance testing outboard sonar system cable harnesses. Recommended test methods are also discussed.

Section 13 provides instructions for handling, installing, testing, and replacing outboard sonar system cable harnesses.

Section 14 lists potential areas of quality deficiency in pressure-proof connectors and notes the applicable document

that must be reviewed in correcting deficiencies.

Section 15 provides a typical failure mode and effects analysis for pressure-proof connector and outboard cable assembly.

A bibliography of technical papers covering connectors, cable, hull penetrators, and materials used in the outboard sonar environment is provided for reference purposes in Section 16.

Appendix A is a glossary of pressure-proof connector plug, and receptacle, hull penetrator, outboard cable, and cable harness terms.

Appendix B provides a number of tables that are of use in covering this subject matter.

Appendix C provides a listing of suppliers and personnel involved in pressure-proof cable, cable harness, connector, and hull penetrator designs and uses.

Appendix D is a list of all who will receive initial distribution of this handbook.

A User Comment Return Form is provided at the back of this handbook. User's comments are encouraged.

SECTION 1

COGNIZANT NAVSEA TECHNICAL AGENCIES

LIST OF TABLES

1.1 Introduction

The following NAVSEA Technical Agencies are responsible for design, development, fabrication, test and maintenance of electrical cables, connectors, hull penetrators, and sonar systems for Navy submarines and surface ships.

1.2 Sonar Systems

Naval Sea Systems Command
Washington, D.C. 20362

Mr. R. E. Heaney SEA 63X5
Mr. C. A. Clark SEA 63X5-1

This code is responsible for the purchase and maintenance of most sonar systems in use by the Navy.

Table 1-1 provides a listing of the transducers in numerical order with connected cables and connectors used on various Navy sonar transducers.

The following documents provide more detailed information on the Navy's sonar systems.

- NAVSEA 0967-LP-410-2020, "Compendium of Test Requirements And Operating Characteristics for NAVSEA Sonar Transducers (U)"(Confidential).
- SE 395-AB-MMD-010/XDCR, "Information Publication - Sonar Transducer/Hydrophone".

The above documents are available from the:

Naval Sea Systems Command
SEA 63X5
Washington, D.C. 20362

TABLE 1-1

Cables and Connectors Used on Navy Sonar Transducers

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
AT-177	TSP-11&RG-64A/U	65		AN/SQS-1,10,10A,11,11A
AT-177A	" "	"		" " " " "
AT-177A-CU326	" "	"		" " " " "
AT-177B	" "	"		" " " " "
AT-186	DSS-3	125		AN/UQC-1
AT-186A	"	"		"
AT-186B	"	"		"
AT-186C	"	"		"
AT-200	"	65		AN/UQN-1,4
AT-200A	"	"	Stuffing Tube	"
AT-200B	"	"		"
AT-200C	"	"		"
AT-200D	"	"		"
AT-200E	"	"		"
AT-200F	"	"		"
AT-200G	"	80		"
"	DSS-3, 1PR-16	100		AN/UQN-1,4; AN/BQQ-6
AT-217	"	30		AN/BQN-1
AT-299	"	65		AN/BQS-2,3
AT-388	FSS-2	55		"
AT-349	TSP-11	65		AN/SQS-10,10A
AT-354	"	"		AN/SQS-11,11A
AT-359B	RG-8/U, RG-59/U	17		AN/UQS-1B,1D
AT-360	DSS-3	50		AN/UQN-2
AT-385	"	80		AN/BQC-1,1A,1B
DT-30	DSS-2	35		AN/UQR
DT-69A	FSS-2	50		AN/BQR-3A
DT-70	"	"		"
DT-85	DSS-3	100	Stuffing	AN/BQR-4
DT-95	"	"	Tube	AN/BQR-4A
DT-143	"	50	Stuffing	AN/UQR
DT-168	"	125	Tube	AN/BQR-2,2A,2B,2C,2D
DT-168B	"	"	Stuffing	AN/BQS-4
DT-168A	"	"	Tube	AN/BQS-4
DT-170	RG-59/U	17	Stuff. Tube	AN/UQS-1, 1B,1D
DT-171	FSS-2	50		AN/BQR-3A
DT-171A	"	31		"
DT-211	DSS-3	75		AN/BQR-7,7B
DT-211A	"	"		"
DT-241	"	150		OMA/BQM-1
DT-241A	"	300		"
DT-242	"	150		"
DT-242A	"	300		"
DT-242B	"	150		"
DT-242C	"	300		"

TABLE 1-1 (Cont'd)

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
DT-276	DSS-3	125	Cable Gland	AN/BQR-7,7B
DT-279	"	"		a. AN/BQR-2,2A,2B,2C,2D; AN/BQS-4
DT-279A	"	"		AN/BQR-2,2A,2B,2C,2D; AN/BQS-4
DT-280	"	100,200,300*		AN/BQQ-3,AN/BQH-2
DT-280A	"	"		" "
DT-280B	"	"		" "
DT-282	"	70	Cable Gland	AN/BQG-2,2A,4
DT-282A	"	"		" " "
DT-282B	"	"		"
DT-282C	"	"		"
DT-282D	"	50		"
DT-283	S2S	70		"
DT-283A	"	"		"
DT-287	FSS-2	150	Cable Gland	AN/BQA-8
DT-288	"	300		"
DT-303	DSS-3	125	MIL-C-22539	+a
DT-305	2SWF-4	100		AN/BQS-8,8A,10,14,20
DT-308	"	40		" " " " "
DT-331	DSS-3	125		+a " " " " "
DT-333	FSS-2	150		AN/BQA-8,8A
DT-334	"	300		" "
DT-338	DSS-3	125		+a
DT-339	FSS-2	50		AN/BQR-3A
DT-365	"	"		AN/BQS-15XN1
DT-369	FSS-2	200		AN/BQH-5
DT-372	Raytheon #43679	110		AN/BQR-19
DT-393	DSS-3	125		+a
DT-506	FSS-2	150		AN/BQA-8,8A
"	"	300		" "
DT-511	2SWF-4	100	Cable Gland	AN/WLR-9
DT-511A	"	"		"
DT-512	2SWF-7	160		"
DT-512A	"	160		"
DT-513	FSS-2	150		AN/BQA-8,8A
"	"	250		" "
DT-513A	FSS-2	150		AN/BQA-8
"	"	250		"
DT-531	FSS-2	150		AN/BQA-8,8A
"	"	250		" "
DT-532	DSS-3	125		AN/BQR-21
DT-537	FSS-2	70	Cable Gland	AN/SQQ-23
DT-538	"	100		"
DT-539	"	150		AN/BQS-3
DT-544	2SWF-7,7PR-16	160	Cable Gland	AN/WLR-12;AN/BQQ-6
DT-574	1PR-A20E	50		AN/BQQ-6
DT-605	2SWF-4	40		AN/BQS-8,10,14
DT-611	1PR-A20E	100		AN/BQR-21

* Length As Requested.

TABLE 1-1 (Cont'd)

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
HS-18	DSS-3	100		DUUG-1
HS-18E	"	"	Stuffing	"
HS-18E(BTD)	"	"	Tube	"
HS-18G(MI)	"	75		"
HS-18G	"	100	Stuffing	"
HS-18H	"	"	Tube	"
HS58DO-300	DSS-3,1PR-16	35		AN/BQN-13,AN/BQQ-6
MX-1905	RG-8/U	17		AN/UQS-1,1B,1D
TR-107	TSP-31	60		b. AN/SQS-4,32,32A,42(V) 52,23B,32C,46(V) Hull
TR-108	TSP-31	60		c. AN/SQS-4,31B,31C,45(V) Hull,31,31A,41(V),51
TR-110	DSS-3	65		AN/SQM-1,AN/UQM-1
TR-111	"	"		" "
TR-112	"	"		" "
TR-113	"	"		" "
TR-114	TSP-31	60		d. AN/SQS-4,30,30A,30B, 40(V),40,30B,30C, 44(V) Hull
TR-114A	"	"		AN/SQS-4,30,30A,30B, 40(V),50,30B,30C, 44(V) Hull
TR-115	"	"		e. AN/SQS-4,29,29A,39(V) 49,29B,29C,43(V) Hull
TR-115A	"	"		AN/SQS-4,29,29A,39(V) 49,29B,29C,43(V) Hull
TR-116	"	"		+b
TR-116A	"	"		+b
TR-117	"	"		+c
TR-117A	"	"		+c
TR-122	DSS-3	80	Cable	AN/BQC-1,1A,1B
TR-122A	DSS-3	"	Gland	AN/BQC-1,1A,1B
TR-122B	"	"		" " "
TR-126	DSS-2	75		AN/WQM
TR-127	"	"		"
TR-128	"	"		"
TR-129	"	"		"
TR-131	TSP-31	60		+e
TR-132	"	"		+b
TR-133	"	"		+e
TR-134	"	"		+d
TR-139	"	125		AN/SQS-4,(Mod 1, Submarine) 49
TR-141	RG-28/U,DSWS-4	"	Stuffing	AN/BQS-4
TR-141A	DSWS-4	"	Tube	"
TR-141B	DSWS-4	"		"

TABLE 1-1 (Cont'd)

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
TR-143	RG-12A/U	135		AN/BQN-3
TR-145	DSS-3	250		AN/BQN-4
TR-146	DSS-3	50		AN/SQN-8
TR-155A	"	15	Cable Gland	AN/BQS-6,6A,6B,11, 12,13
TR-155B	"	"		AN/BQS-6,6A,6B,11, 12,13
TR-155C	"	"		AN/BQS-6,6A,6B,11, 12,13
TR-155D	"	"		AN/BQS-6,6A,6B,11, 12,13
TR-155E	"	18		AN/BQS-6,6A,6B,11, 12,13
TR-155F	"	18		AN/BQQ-5,5A,5B
TR-155G	"	"		"
TR-164	"	250	Stuff. Tube	AN/BQN-4A
TR-167A	7SS-2	125	MIL-C-22539	AN/BQH-1A,1B
TR-167B	7SS-2,3PR-16	"		AN/BQH-1A,1B;AN/BQQ-6
TR-167C	7SS-2,3PR-16	"		AN/BQH-1A,1B;AN/BQQ-6
TR-170	GI #91E-CA-0033	30		AN/SQA-10;AN/SQS-31B, 31C,45(V)
TR-170A	"	"		AN/SQA-10;AN/SQS-31B, 31C,45(V)
TR-170B	"	"		AN/SQA-10;AN/SQS-31B, 32C,45(V)
TR-171	"	"		AN/SQA-10;AN/SQS-32B, 32C,46(V)
TR-171A	"	"		AN/SQA-10;AN/SQS-32B, 32C,46(V)
TR-171B	"	"		AN/SQA-10;AN/SQS-32B, 32C,46(V)
TR-173(TD)	RG-58A/U	25		AN/SQQ-14
TR-177(SC)	Sangamo#820742	50		AN/SQS-23
TR-183	TSP-31	60		+e
TR-183A	"	"		+e
TR-184	"	"		+d
TR-184A	"	"		+d
TR-185	"	"		+c
TR-185A	"	"		+c
TR-186	"	"		+b
TR-188	Sangamo#829026	30		AN/SQA-10;AN/SQS-29B, 29C,43(V)
TR-188A	GI#91E-CA-0033	30		AN/SQS-10;AN/SQS-29B, 29C,43(V)
TR-186A	TSP-31	60		+b
TR-189	Sangamo#829026	30		AN/SQS-10;AN/SQS-30B, 30C,44(V)
TR-189A	GI#91E-CA-0033	"		AN/SQS-10;AN/SQS-30B, 30C,44(V)

TABLE 1-1 (Cont'd)

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
TR-191(SC) TR-191A"	Massa#C30829-501 "	50 "		AN/SQS-23 "
TR-192 TR-192A TR-192B	DSS-3,DSS-4 " " " "	65 " "	Stuffing Tube	AN/UQN-1,4 " " " "
TR-193 TR-193A TR-193B TR-193B	DSS-3 " " "	150 " 30 150	Cable Gland	AN/UQC-1 " " "
TR-194(MC) TR-195(MC)	Massa#C-30732-2 "	26 "		AN/SQA-10;AN/SQS-29B, 29C AN/SQA-10;AN/SQS-30B, 30C,44(V)
TR-196 TR-197(SC)	TSP-11,RG-27/U, RG-130/U Massa#C-30829-501	50 "		AN/SQS-17 AN/SQS-23
TR-198(SC) TR-203(SC)	GE#C77C705423 Edo #42892	118 105		AN/SQS-26AXR AN/SQS-26BX
TR-204	TSP-31	85		AN/SQS-36
TR-205 TR-205A	DSS-2 "	100 "		AN/WQM-3 "
TR-208(SC) TR-208A(SC) TR-208A "	Massa#C320829-501 " " " "	50 " 100	Cable Gland and Joy Connector	AN/SQS-23 " "
TR-212 TR-213 TR-214 TR-215 TR-216 TR-217 TR-217A	2SWF-4 DSS-3 " FSS-2 DSS-3 " "	100 90 75 22 75 " "	MIL-C-22539	AN/BQS-8,8A,10,14 " " " " " " " " " " " ",20 " " " " " " " " " " " " " " "
TR-225	DSS-2	100		AN/WQM-3
TR-227(SC)	GE#77D603108	118		AN/SQS-26CX
TR-229(FTC) TR-229(FTC) TR-230(FTC) TR-231	Edo #57026 Edo #60372-1 & #58112-1 Edo #57026 Edo #60369-1 (Pigtail)	650 5 7 650 2		AN/SQS-35 AN/SQS-38 AN/SQS-35(V) AN/SQS-38
TR-232 TR-232 TR-233 TR-233	DSS-3,1PR-16 " " " " " "	30 175 30 175	Cable Gland	AN/WQC-2,AN/BQQ-6 " " " " " "
TR-237 TR-238	Sangamo#867484 "	50 "	Cable Gland and Joy Connector	AN/SQS-4,29, 29A, 30, 30A,39(V),29B,29C,30B, 30C,43(V),45(V)Hull, 51,52 AN/SQS-4,31,31A,32, 32A,41(V),42(V),31B, 31C,32B, 32C,45(V), 46(V) Hull

TABLE 1-1 (Cont'd)

Transducer	Cable Type	Cable Length (FT)	Transducer Connector	System
TR-242	FSS-2	50		AN/BQS-15,AN/BQQ-6
TR-255	Sangamo#2196	150		AN/SQS-4,Mod 1 & 2 Submarine), 40,50
TR-256	DSS-3	125		AN/UQN-1,4;AN/BQQ-6
TR-281	"	175		AN/BQS-15
TR-282	"	"		"
TR-297	DSS-3	100		AN/UQN-1 4; AN/BQQ-6
TR-298	"	"		" " "
TR-302	2SWF-3	150		AN/BQN-17
TR-316	FSS-2	22	MIL-C-22539	AN/BQS-10,14,18
TR-317	SPECIAL		CABLE	AN/BQQ-5
TR-318	(2 cond.SHIELDED)		GLAND	"
TR-321	7SS-2	125	MIL-C-22539	AN/BQH-IC

+a)
+b)
+c) Refer to respective systems previously
+d) listed
e)

(TD) = Test Ducer
(SC) = Stave Cable
(MC) = Main Cable
(FTC) = Faired Tow Cable

NOTE: See Table 3-11.

1.3 Pressure-Proof Electrical Connectors, Cable Harnesses, and Hull Penetrators

Naval Sea Systems Command
Washington, D.C. 20362
Code 54303
Mr. J. E. Regan

This code is responsible for the design and test of components and the preparation and updating of the documents listed below.

The following is a listing of Military Specifications, Handbooks, Procedures and related documents which have been prepared by this NAVSEA Code to satisfy the Navy's requirements in pressure-proof, harnesses, connectors and hull penetrators.

- MIL-C-24231 (SHIPS), "Connectors, Plugs, Receptacles, Adapters, Hull Inserts, and Hull Insert Plugs, Pressure-Proof"

- MIL-C-24217 (SEA), "Connectors, Electrical Deep Submergence, Submarine"

- MIL-C-22249 (SHIPS), "Connector Sets, Electrical, Hermetically Sealed, Submarine"

- MIL-C-XXXXX, "Connectors, Electrical, Miniature, Pressure-Proof"

- MIL-M-24041 (SHIPS), "Molding and Potting Compound, Chemically Cured Polyurethane - (Polyether - Based)"

- MIL-C-24235, "Stuffing Tubes, Metal, and Packing Assemblies for Electrical Cables"

* NAVSEA Drawing 815-1197170, "Connectors, Hermetically Sealed, 3, 4 and 5 No. 12 and 8 No. 16 Pins", (MIL-C-22539 - Cancelled for new design)

* NAVSHIPS 0962-022-2010, "Molding and Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables"

* NAVSEA Drawing NR-1-302-2663185, "Wiring, Molding and Testing, Installation, Maintenance, and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators"

* NAVSEA S9061-AA-MMA-010/SSBN-726 Class, "Technical Manual - Maintenance and Repair Instructions for Pressure Hull Electrical Penetrators and Associated Outboard Components"

* NAVSEA S9074-AA-MMO-010/DSV-3, 4, "Technical Manual - Fabrication, Installation, Maintenance and Repair, Outboard Cable Harness Assembly Turtle (DSV-3) and Sea Cliff (DSV-4).

* NAVSEA Drawing 815-1197255, "Epoxy Splice Kit for DSS-3 Cable and Plug Assembly Repair"

* NAVSEA Drawing 815-1197377, "Connector - Watertight - 5 Pin"

* AD888281, "Handbook of Vehicle Electrical Penetrators, Connectors and Harnesses for Deep Ocean Applications"

- NAVSEA 03TH-74-010, "Handbook of Pressure-Proof Electrical Harness and Termination Technology for Deep Ocean Applications"

- Electric Boat Division CPG 1145, "Installation Procedures, TRIDENT Outboard Electrical Harnesses and Hull Penetrators"

- Electric Boat Division Specification CPG 1022, "Penetrators, Electrical, TRIDENT Submarine"

- Electric Boat Division Specification CPG 1025, "Penetrators, Connector Types, Electrical, TRIDENT Submarine"

- Electric Boat Division Specification CPG 1027, "Connector, Plug and In-line Receptacle, Molded Electrical, 3, 4, 7, 9, 14, 24, 30 and 40 Conductor, Pressure-Proof"

- Electric Boat Division CPG 1060, "Procedures for Wiring, Molding, Inspection and Testing Pressure-Proof Electrical Connectors for TRIDENT Submarines"

- Electric Boat Division CPG 1099, "Splicing Procedure for Neoprene and Polyurethane Jacketed Cables on TRIDENT Submarines"

- Electric Boat Division CPG 1326, "Procedures for Molding, Inspection and Testing Transducer Cable Glands for TRIDENT Submarines"

- Lockheed Specification RV-S-2171 "Electrical Connectors, Deep Submergence, Pressure Compensated"

- Lockheed Specification RV-S-2171 "Fabrication of Pressure Compensated, Oil Filled Harnesses"

- Electric Boat Division CPG 1096, "Procedure for Splicing Type 1PR-A20E Polyethylene Jacketed Cables on TRIDENT Submarines"

- NAVSEA Drawing No.: DSV-4-304-5155928, "General Specification for Connectors, Oil Filled for Deep Submergence Vehicle Cabling"

- NAVSEA Drawing No.: DSV-4-803-5155923, "Development and Fabrication Specifications for Penetrator, Electrical, Sea Cliff (DSV-4), 20,000 Foot Modification" (2 Parts)

- Lockheed Specification RV-S-0104, "Fabrication of Submersible Electrical Harness Assemblies"

- Lockheed Specification RV-S-0259, "Thru Hull Connectors, Electrical, Deep Submergence"

- Lockheed Specification RV-S-0288, "Installation of Electrical Cable and Auxiliary Components for Deep Submergence Vehicles"

- NAVSEA Drawing No.: 815-1197218, "Hull Fitting for AN/BQQ-1 Sonar-Sym No. 538"

- Newport News Shipyard Drawing 185785, "Multiple Cable Connector Detail Standard"

- Newport News Shipyard Drawing 185786, "Receptacle Details Standard"

- Newport News Shipyard Drawing 185783, "Molded Plug Details Standard"

- Newport News Shipyard Drawing 185784, "Single Cable Connector Details Standard"

The above noted Military Specification and Military Standard Documents are available from:

Commanding Officer
Naval Publications and Forms Center
Attention: N.P.F.C. 105
5801 Tabor Avenue
Philadelphia, PA 19120

All other specifications, drawings and handbooks are available from:

Naval Sea Systems Command
SEA 5433
Washington, D.C. 20362

1.4 Outboard Electrical Cables

Naval Sea Systems Command
Washington, D.C. 20362
Code 5422
Mr. S. Wong

This code is responsible for the design and test of cables and the preparation and updating of the documents listed below.

1.4 (Continued)

The following Military Specifications and Specification Data Sheets have been prepared by the NAVSEA code in the outboard electrical cable area.

- MIL-C-915, "Cable and Cord, Electrical, for Shipboard Use"

- MIL-W-16878, "Wire, Electrical, Insulated, High Temperature"

- DDS 304-2, "Design Data Sheets - Electric Cable Ratings and Characteristics"

- NAVSEA 0981-052-8090, "Cable Comparison Guide - Data Pertaining to Electric Shipboard Cable"

- AD877-774, "Handbook of Electrical Cable Technology for Deep Ocean Applications"

- Electric Boat Division CPG 1000/3, "Cable, Electrical, One Twisted Pair, Fluoropolymer Insulation, for TRIDENT Submarine Shipboard Use Type 1PR-16"

- Electric Boat Division CPG 1000/4, "Cable Electrical, One Shielded Twisted Pair, No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 1SPR-16

- NAVSEC Procurement Specification, "Cable Electrical, One Twisted Pair, AWG-20, for TRIDENT Submarine Outboard Use (Not for Inboard Use) Type 1PR-A20E"

- Electric Boat Division CPG 1000/8, "Cable, Electrical, Seven Shielded Twisted Pairs with Overall Shield, No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 7SPR-16S

- Electric Boat Division 1000/14, "Cable, Electrical, Twisted Triad, No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 1TR-16

- Electric Boat Division CPG 1000/16, "Cable, Electrical, Twisted Quad, No. 16 GA, Fluoropolymer Insulation, for TRIDENT Submarine Outboard Use" Type 1Q-16

- Electric Boat Division CPG 1000/17, "Cable, Electrical, Seven No. 16 GA Conductors, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 7PL-16

- Electric Boat Division CPG 1000/18, "Cable, Electrical, Seven Twisted Pairs No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 7PR-16

- Electric Boat Division CPG 1000/19, "Cable, Electrical, Two Shielded Twisted Pairs, No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use" Type 2SPR-16

- Electric Boat Division CPG 1000/20, "Cable, Electrical, Three Twisted Pairs, No. 16 GA, Fluoropolymer Insulation for TRIDENT Submarine Outboard Use", Type 3PR-16

- Lockheed Specification RV-S-0162, "Cable, Electrical, (Deep Submergence)"

The above noted Military Specification Documents are available from:

Commanding Officer
Naval Publications and Forms Center
Attention: N.P.F.C. 105
5801 Tabor Avenue
Philadelphia, PA 19120

All other specifications and hand books are available from:

Naval Sea Systems Command
SEA 5422
Washington, D.C. 20362

The Naval Electronic Systems Command is responsible for the Navy's interests in the coaxial cable Military Specification.

Naval Electronic Systems Command
Washington, D.C. 20362
Code ELEX 50452
Mr. J. Kerr

- MIL-C-17, 'Cables, Radio Frequency, Flexible and Semi-rigid"

The above noted Military Specification Document is available from:

Commanding Officer
Naval Publications and Forms Center
Attention: N. P. F. C. 105
5801 Tabor Avenue
Philadelphia, PA 19120

SECTION 2

NAVSEA APPROVED PRESSURE-PROOF ELECTRICAL CONNECTORS

LIST OF FIGURES

LIST OF TABLES

2.1 Introduction

This section describes the pressure-proof electrical connectors in use on submarines, surface ships and deep submergence vehicles of the U.S. Navy. The following connectors are the preferred types to be used on Navy vehicles for outboard sonar system applications:

- Submarines - MIL-C-24231 Connectors.
- Surface Ships - Watertight Neoprene Connectors.
- Deep Submergence Vehicles - MIL-C-24217 Connectors.

It is noted that certain sonar system component designs have required the use of connectors other than those listed above. These connectors are also described and detailed in the following paragraphs.

Table 2-1 provides a listing of test requirements for the preferred pressure-proof sonar connectors given above.

2.2 MIL-C-24231 Connectors

The MIL-C-24231 pressure-proof connectors, better known as the "Portsmouth Connectors" were designed and tested at the Portsmouth Naval Shipyard, Kittery, Maine, for NAVSEA in the late 1950's. The connectors were primarily designed for submarine use in conjunction with the connectorized hull penetrator also detailed in MIL-C-24231, Reference 2-1. The connectors were also incorporated into jackbox, pressure-proof lights and other pressure-proof components at that time. The connectorized hull penetrators, single and multi-connector types, replaced the stuffing tube penetrators in 1960. Since that time all new submarine construction has made use of the MIL-C-24231 connectors and hull penetrators. Figure 2-1 is a detail of a typical MIL-C-24231 connector design. As this connector is used at the hull penetrator end of the submarine outboard cable, the Navy prefers that this type connector also be located at the component end of the cable.

The MIL-C-24231 connectors are comprised of a Monel plug and receptacle body and a nickel aluminum bronze coupling ring. An O-ring seals the plug to the receptacle. The receptacle is normally sealed and retained to the hull penetrator or component by welding. A molded receptacle insert insulates and provides a water barrier for the pin contacts located in the receptacle. The insert is O-ring sealed to the receptacle body. Socket contacts are located and insulated in the plug with a molded polyurethane insert. The contacts are the solder type. A key is located in the plug sleeve and a keyway in the receptacle body. A pin is also located in the receptacle body to polarize the insert assembly to the receptacle. A nylon insert is located in the receptacle thread to lock the plug coupling in place. A molded polyurethane rubber boot seals plug to the cable; as well as providing cable strain relief. The coupling is fastened to the receptacle with a hook type spanner wrench. Table 2-2 provides a listing of the standard connector types and sizes and connector assembly part numbers.

TABLE 2-1

Pressure-Proof Connector Test Requirements

Connector Type	Hydrostatic Pressure (psi)	Insulation Resistance (megohms)	Withstanding Voltage VAC (RMS)	Working Voltage VAC (RMS)
MIL-C-24231	2000	2000	1600	600
MIL-C-24217	10000	5000	1880	625
Surface Ship Connector	100	100	1500	---

TABLE 2-2

MIL-C-24231 Connector Sizes, Types and Part Numbers

Contact Size	Plug Type	Plug Part Number	Receptacle Part Number
3 No. 16	Straight	M24231/1-001	M24231/12-001
4 No. 16	Straight	M24231/1-002	M24231/12-003
5 No. 16	Straight	M24231/1-003	M24231/12-004
3 No. 16	90^o	M24231/2-001	---
4 No. 16	90^o	M24231/2-002	---
5 No. 16	90^o	M24231/2-003	---
7 No. 16	Straight	M24231/3-001	M24231/13-001
9 No. 16	Straight	M24231/3-002	---
7 No. 16	90^o	M24231/3-003	---
9 No. 16	90^o	M24231/3-004	---
14 No. 16	Straight	M24231/4-001	M24231/14-001
24 No. 16	Straight	M24231/4-002	M24231/14-002
30 No. 16	Straight	M24231/4-003	M24231/14-003
40 No. 16	Straight	M24231/4-004	M24231/14-004

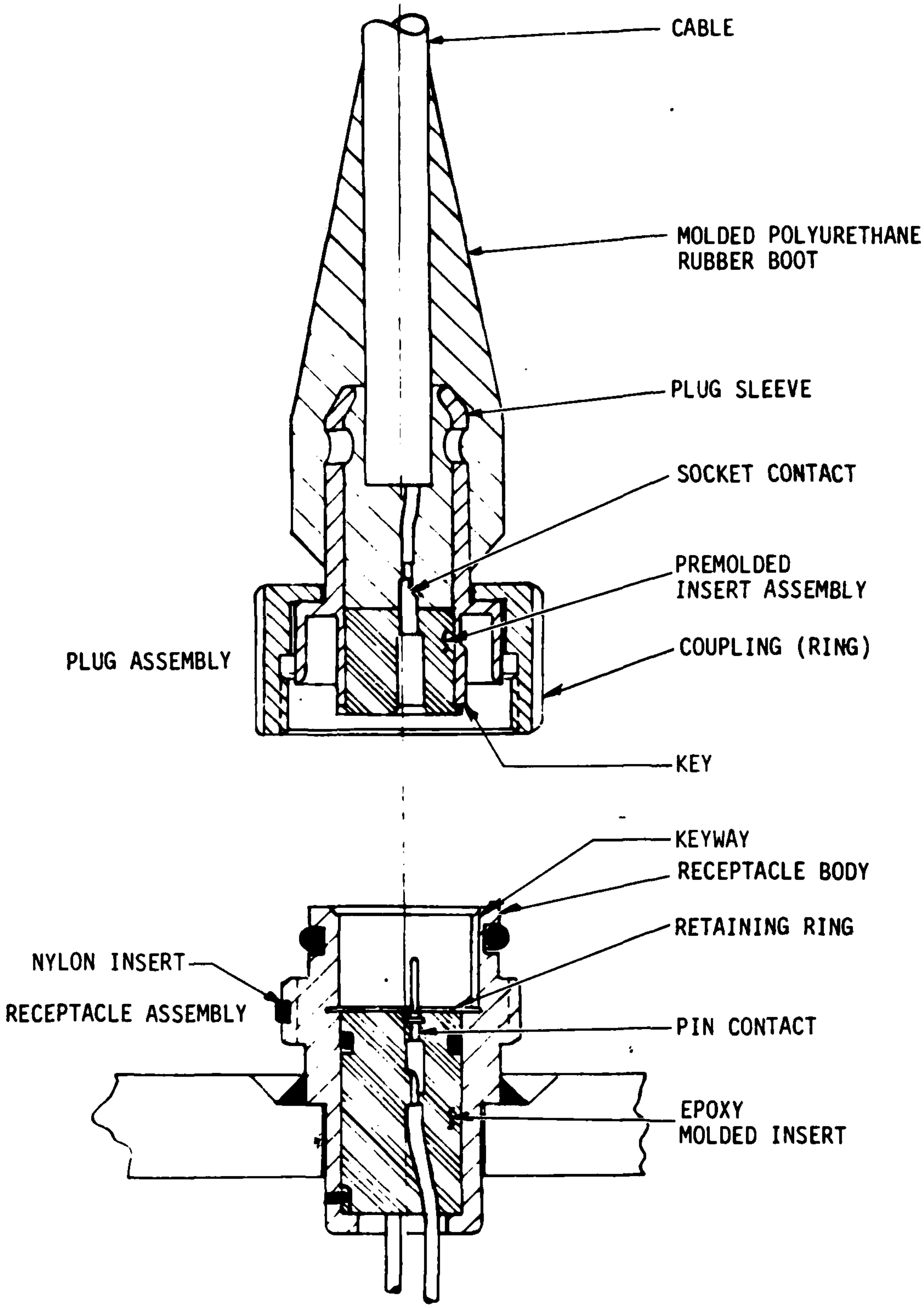


FIGURE 2-1 MIL-C-24231 CONNECTOR ASSEMBLY

2.3 Surface Ship Connectors

Surface ship sonar systems make use of an in-line molded neoprene connector assembly which is belived to have been originally developed by the Joy Manufacturing Company over 30 years ago. There is no military specification for this connector assembly at this time. The assembly is simple in design and is relatively inexpensive to fabricate as it has few metal parts. See Figure 2-2 and Reference 2-2.

Connector polarization is achieved by lining up the plug and receptacle polarization buttons molded into the connector body. Also the pin and socket contacts are a different size (diameter) which serves to prevent improper connector polarization. The plug-to-receptacle seal is achieved by an interference fit between the rubber plug and receptacle body. A rubber to rubber interference seal may also be provided between the shoulders of the plug and receptacle when mated and held together with the plastic plug and receptacle coupling rings. The male and female coupling rings are used to lock the plug and receptacle in place following assembly. The coupling rings are not used in the mating process as with most other connector designs.

Connector manufacturers have fabricated these units in accordance with the design and specification requirements of the transducer manufacturer. Standard Navy drawings or specifications are not known to exist.

The connector assembly used on surface ship transducers is part of an outboard cable harness assembly depicted in Figure 2-3. The plug connector houses two socket contacts and is fitted with a male coupling ring. The plug cable is wired and sealed to the base of the transducer. A neoprene jacketed twisted

2.3 (Continued)

conductor pair cable designated DSU-2 is wired and molded to the plug and receptacle connectors. In past years the standard commercial SO type cables have also been used. The receptacle connector houses two pin contacts and is wired and molded to a DSU-2 cable which in turn is wired and molded into an "8 to 1" cable splice. The larger cable is an eight shielded twisted pair construction and is sealed with a cable stuffing tube as it passes through the ships hull.

Non standard pin and socket contacts are used in this connector design. A standard size 12 pin contact is .094 ± .001 inches in diameter. The small pin contact used in this design is approximately .090 ± .001 inches in diameter. A standard size 14 pin contact is .125 ± .001 inches in diameter. The larger contact in this connector is approximately .122 ± .001 inches in diameter.

The plug and receptacle connectors are basically an all neoprene molded construction. Pin and socket contacts, as applicable, are soldered to the cable conductors prior to molding. The Massa Company design prepots the socket contacts with a glass filled phenolic material per MIL-M-14.

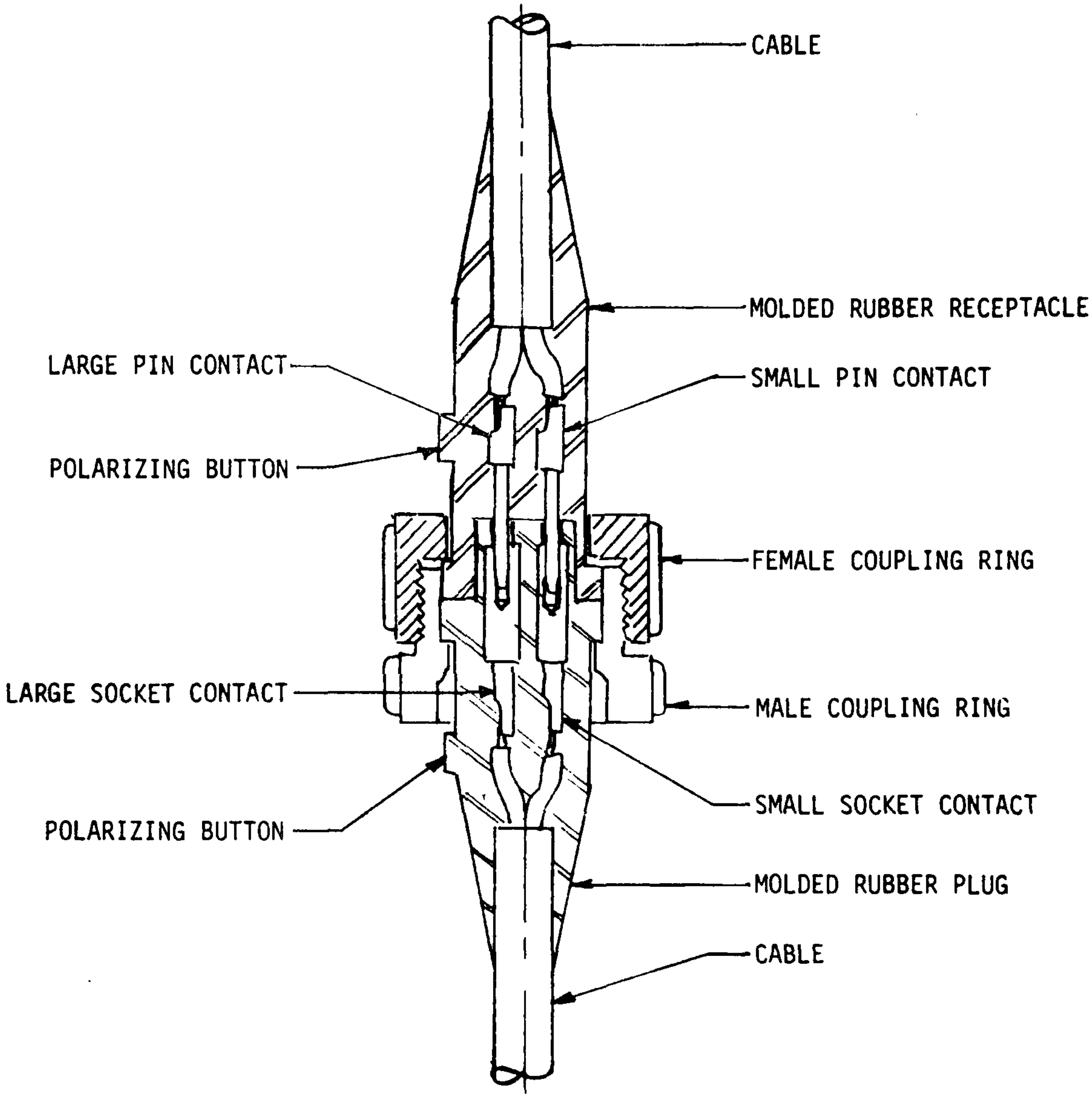


FIGURE 2-2 SURFACE SHIP CONNECTOR ASSEMBLY

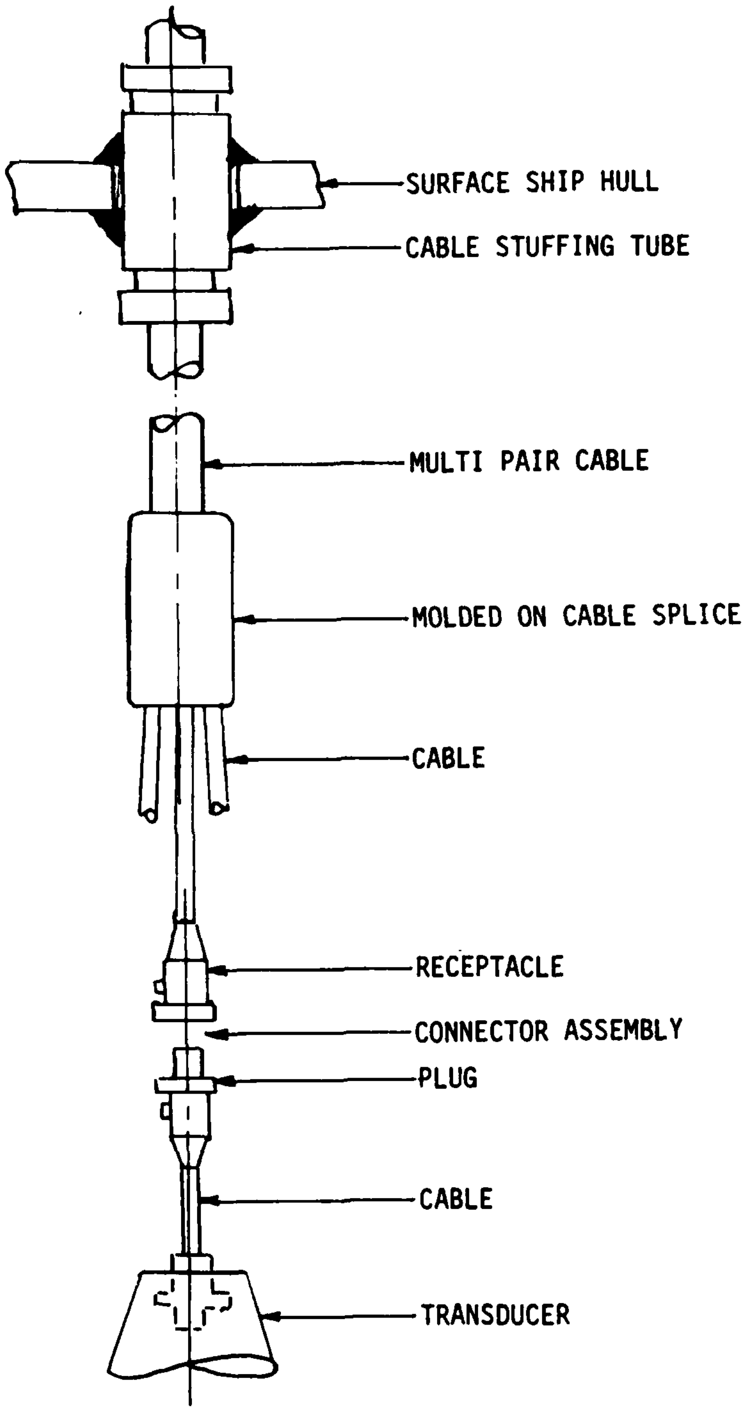


FIGURE 2-3 TYPICAL SURFACE SHIP CABLE HARNESS ASSEMBLY

2.4 MIL-C-24217 Connectors

The MIL-C-24217 connectors, Reference 2-3, were designed and tested at Electric Boat Division for NAVSEA in the early 1960's. The connectors were originally designed for use on Deep Submergence Vehicles of the U.S. Navy. As a result, they have found use on the NR-1, DSRV, Sea Cliff, Turtle, Personnel Transfer Capsules, and in many tactical submarine applications. The connectors are used on sonar system components which are oil filled as the receptacles have pin contacts hermetically sealed and insulated with compression glass. This type of receptacle provides an ideal barrier for the oil filled component. Also, the receptacles are fabricated from type 316L stainless steel. This allows welding to the component housings which are usually fabricated from type 304 or 316 stainless steel. As these connectors are somewhat smaller in size than the MIL-C-24231 types, they have also been used where available space did not allow the use of the MIL-C-24231 types. A typical connector assembly is detailed in Figure 2-4.

The MIL-C-24217 connectors have a 316 stainless steel plug and receptacle body and a nickel aluminum bronze coupling ring. Redundant radial and gasket type O-rings seal the plug to the receptacle. The receptacle is normally sealed and retained to the component by welding. However, the specification details many other receptacle types which allow mounting by other methods. These are covered in Section 10. The pin contacts in the receptacle are sealed and insulated in the header with compression glass. The header thickness allows for watertight sealing to 10,000 psi. A clear RTV 615 silicone contact gasket is bonded to the receptacle header with General Electric Co. SS4120 primer. This gasket serves to increase the electrical leakage path between contacts.

2.4 (Continued)

Socket contacts are located in the plug assembly and are insulated in a diallyl phthalate plastic insulator. The number 16 size contacts are the crimp type and the larger sizes are the solder types. A key crimped into the plug body polarizes the slotted insulator to the plug body. A keyway is located in the plug body and a key in the receptacle to provide proper polarization. A molded polyurethane or neoprene rubber boot seals the cable to the plug assembly. The plug coupling ring is fastened to the receptacle with a pin type spanner wrench. Table 2-3 is a listing of the more standard connector types and sizes and connector assembly part numbers.

TABLE 2-3

MIL-C-24217 Connector Sizes, Types and Part Numbers

Contact Size	Plug Type	Plug Part Number	Welded Receptacle Part Number
3 No. 16	Straight	M24217/7-001	M24217/1-001
5 No. 16	Straight	M24217/7-003	M24217/1-002
9 No. 16	Straight	M24217/7-005	M24217/1-003
14 No. 16	Straight	M24217/7-007	M24217/1-004
24 No. 16	Straight	M24217/7-009	M24217/1-005
37 No. 16	Straight	M24217/7-011	M24217/1-006
48 No. 16	Straight	M24217/7-013	M24217/1-007
3 No. 12	Straight	M24217/7-015	M24217/1-008
5 No. 12	Straight	M24217/7-016	M24217/1-009
9 No. 12	Straight	M24217/7-017	M24217/1-010
3 No. 8	Straight	M24217/7-018	M24217/1-011
3 No. 4	Straight	M24217/7-019	M24217/1-012
3/8 - 3/12	Straight	M24217/7-020	M24217/1-013
2/0 - 4/12	Straight	M24217/7-021	M24217/1-014

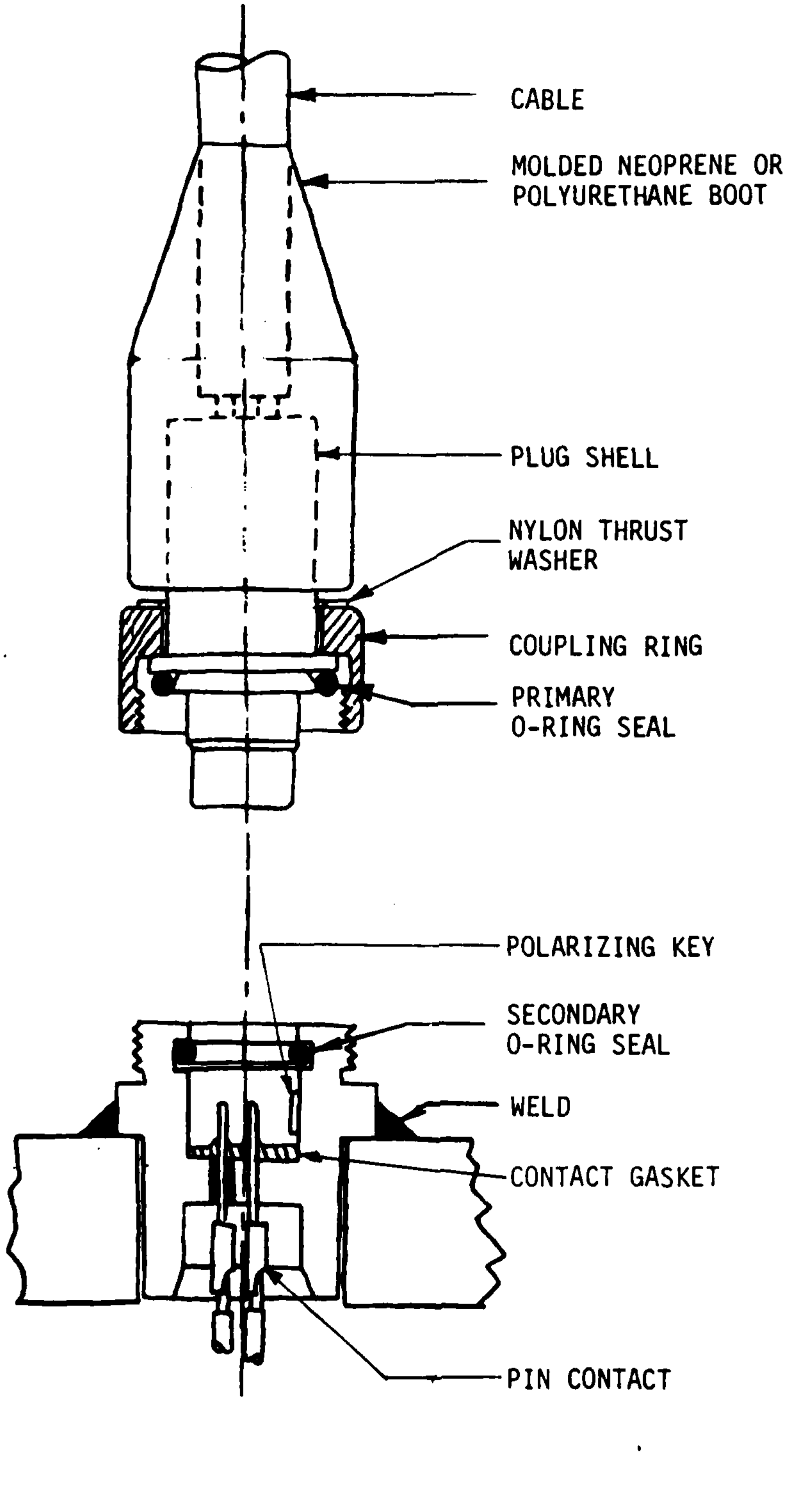


FIGURE 2-4 MIL-C-24217 CONNECTOR ASSEMBLY

2.5 MIL-C-22539 Connectors

This connector design was developed and tested at Electric Boat Division for NAVSEA in 1959. The connectors were designed for use in Navy military submarine applications. As the designs are glass hermetically sealed types, they were primarily used at the component interface on units which were oil filled. With the advent of the MIL-C-24217 connector designs in the mid 1960's, the military specification was cancelled by NAVSEA for new design work. These connectors, however, are still in use. NAVSEA Drawing No. 815-1197170, Reference 2-4, is still active and should be used in ordering replacement assemblies. This connector assembly has performed satisfactorily in service. However, it should be replaced by the smaller MIL-C-24217 types for new design Navy applications. The connector design and materials of fabrication are similar to the MIL-C-24217 connector with the exception of the socket contacts which are the solder type. The socket contacts are also O-ring sealed to the insulator assembly. It should be noted that this connector is not designed for Deep Submergence applications. Figure 2-5 provides details of design.

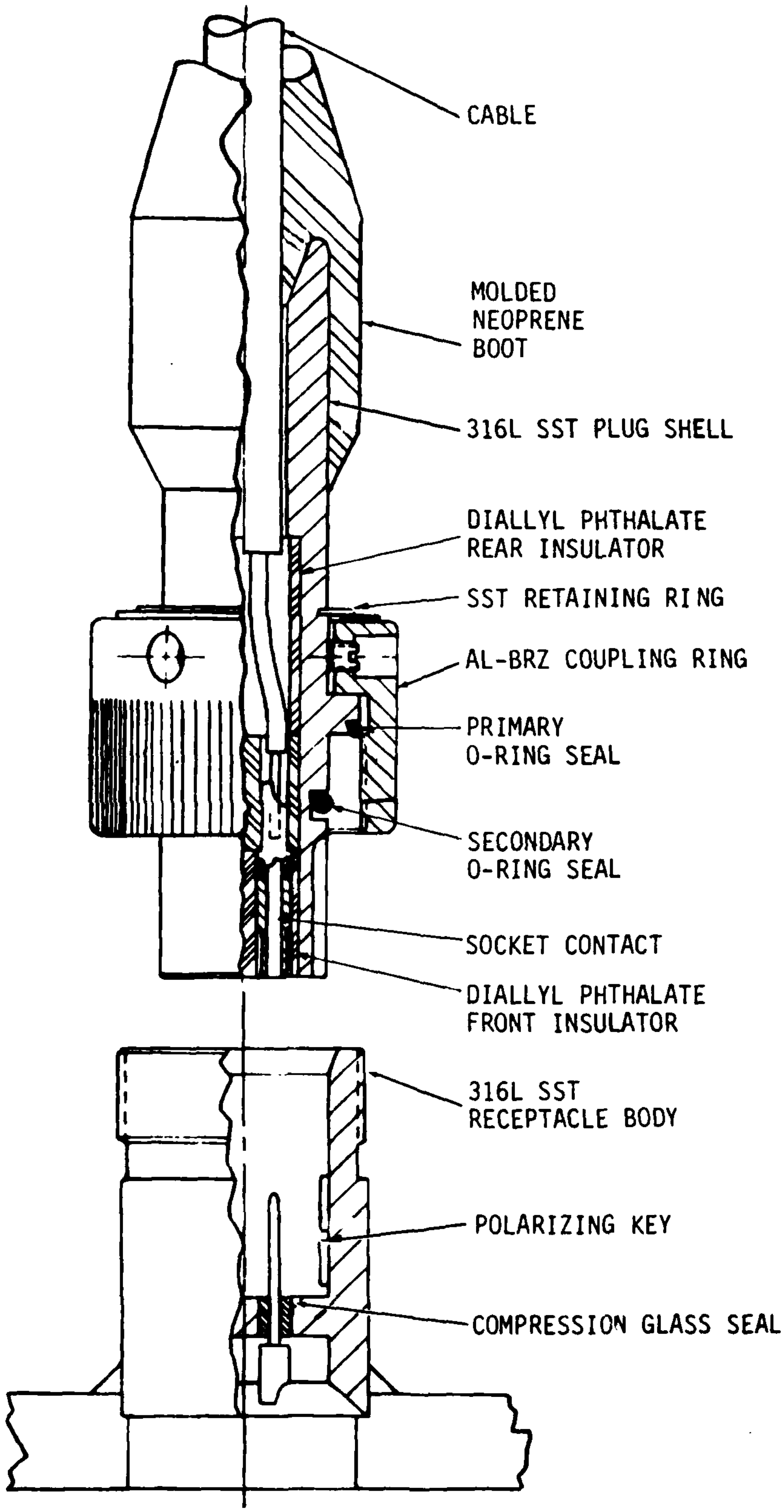


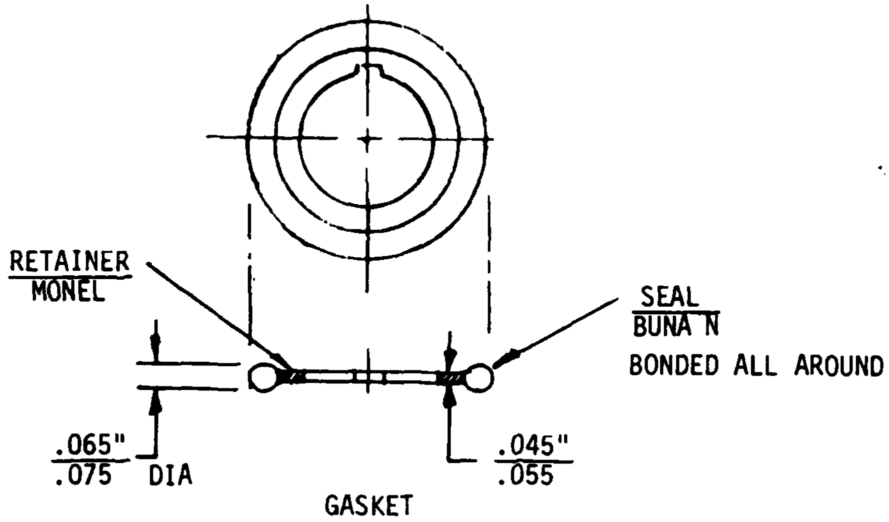
FIGURE 2-5 MIL-C-22539 CONNECTOR ASSEMBLY

2.6 TRIDENT Submarine Connectors

Pressure-proof connectors designs used outboard on TRIDENT submarines are the MIL-C-24231, MIL-C-24217, and the MIL-C-24217 type with glass sealed plugs. The MIL-C-24231 plugs were modified to include a secondary plug-to-receptacle seal gasket developed by the Naval Underwater Systems Center, New London, Connecticut. See Figure 2-6. The plug socket contact insert was also redesigned to provide for bonding the polyurethane insert material to the individual socket contacts in the area shown on Figure 2-6. The connector is detailed in Electric Boat Division Specification CPG 1027, Reference 2-5.

The glass sealed MIL-C-24217 type plug design, depicted in Figure 2-7 and manufactured by D. G. O'Brien, Inc., Reference 2-6, is used on a number of TRIDENT sonar systems. Solder type pin contacts are glass sealed in the plug header. Double ended socket contacts are insulated in the front end of the plug with split insulators fabricated from Delrin (Acetal Copolymer) plastic.

Figure 2-8 details a MIL-C-24217 in line receptacle which has a polyethylene jacketed cable and boot seal. The design is detailed in Electric Boat Division Specification CPG 1265, Reference 2-7.



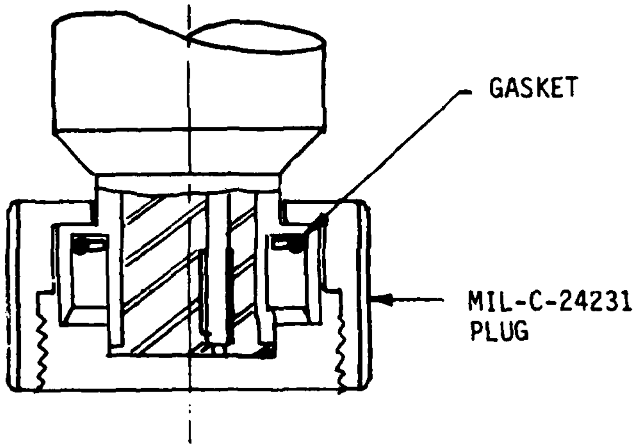
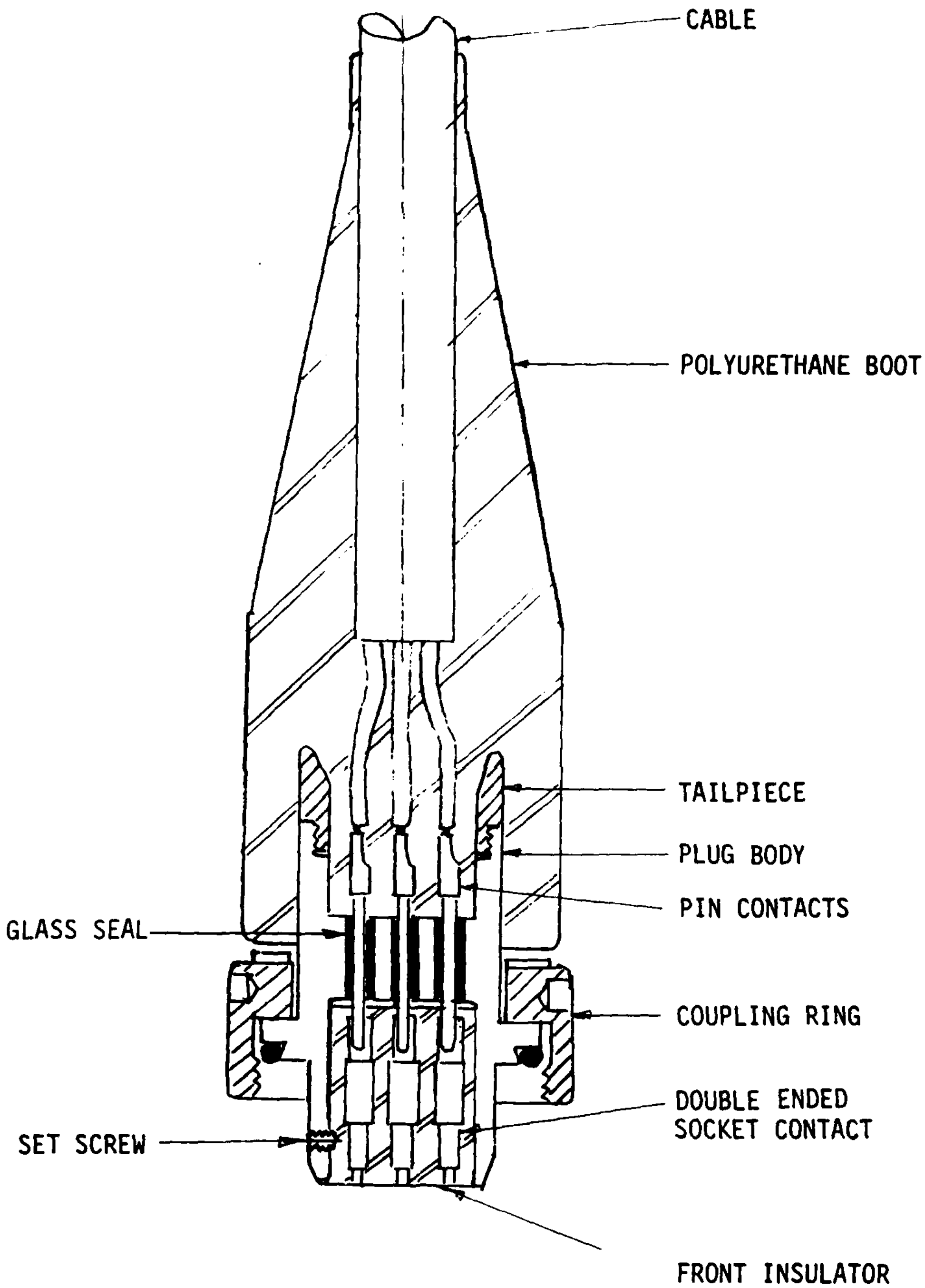


FIGURE 2-6 TRIDENT MIL-C-24231 TYPE PLUG ASSEMBLY



PLUG ASSEMBLY D.G. O'BRIEN, INC., PART NO. C17C1003602

FIGURE 2-7 D.G. O'BRIEN, INC., CPG 1027 TYPE GLASS SEALED PLUG

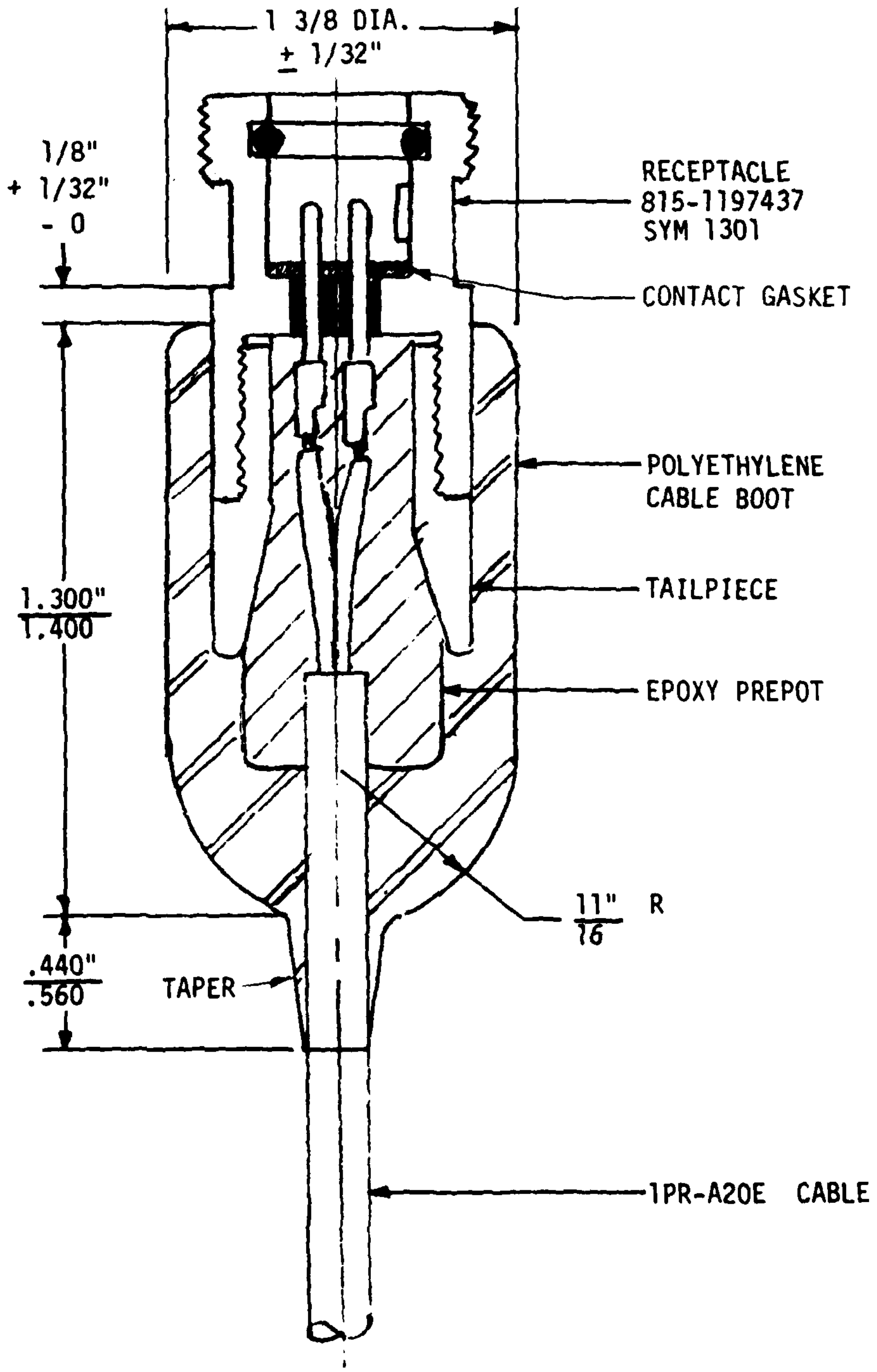


FIGURE 2-8 TRIDENT POLYETHYLENE MOLDED MIL-C-24217 CONNECTOR RECEPTACLE

2.7 Miniature Pressure-Proof Connectors

A miniature pressure-proof connector has been designed for Navy use in limited depth (1000 psi) submergence applications. Its primary use to date has been in Navy diver equipment. The connector assembly is shown in Figure 2-9 and detailed in Reference 2-8. The plug and receptacle shell are type 316 stainless steel. The coupling ring is nickel aluminum bronze. The receptacle is designed for O-ring sealing and thread retention to the component. The No. 20 size pin contacts in the receptacle are solid glass sealed and insulated. A radial O-ring gasket located in the receptacle provides the plug-to-receptacle seal. Five keyways located in the receptacle provide polarization with the plug keys. Socket contacts are housed in a rubber insulator which is in turn located in an aluminum housing which makes up the front end of the plug shell. The aluminum is not exposed to sea water in service.

A proposed Military Specification has been prepared for this connector design and it is presently in the Navy approval process. The connector is available in 3, 4 and 6 number 20 size contacts. The overall diameter of this connector design is less than 1 inch.

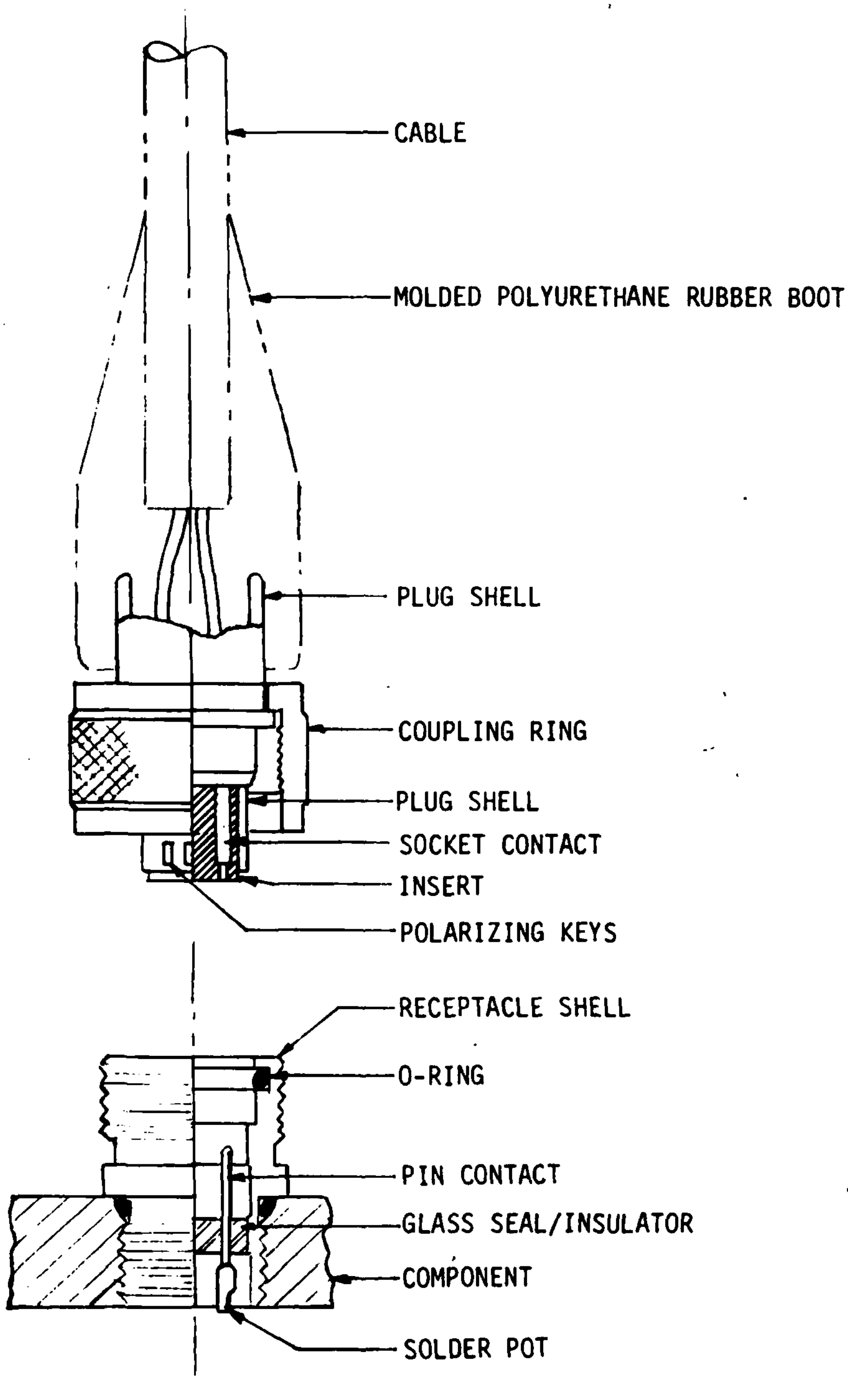


FIGURE 2-9 MINIATURE PRESSURE-PROOF CONNECTOR

2.8 DOLPHIN Submarine Connectors

Connectors used outboard on the DOLPHIN submarine are the MIL-C-24231 type except that the receptacles have glass sealed pin contacts. The receptacles are retained in the hull penetrators by threads and are seal welded. The receptacle body is fitted with cylindrical fins to provide for heat dissipation during the welding operation. The connector assembly is shown on Figure 2-10 and detailed in Reference 2-9.

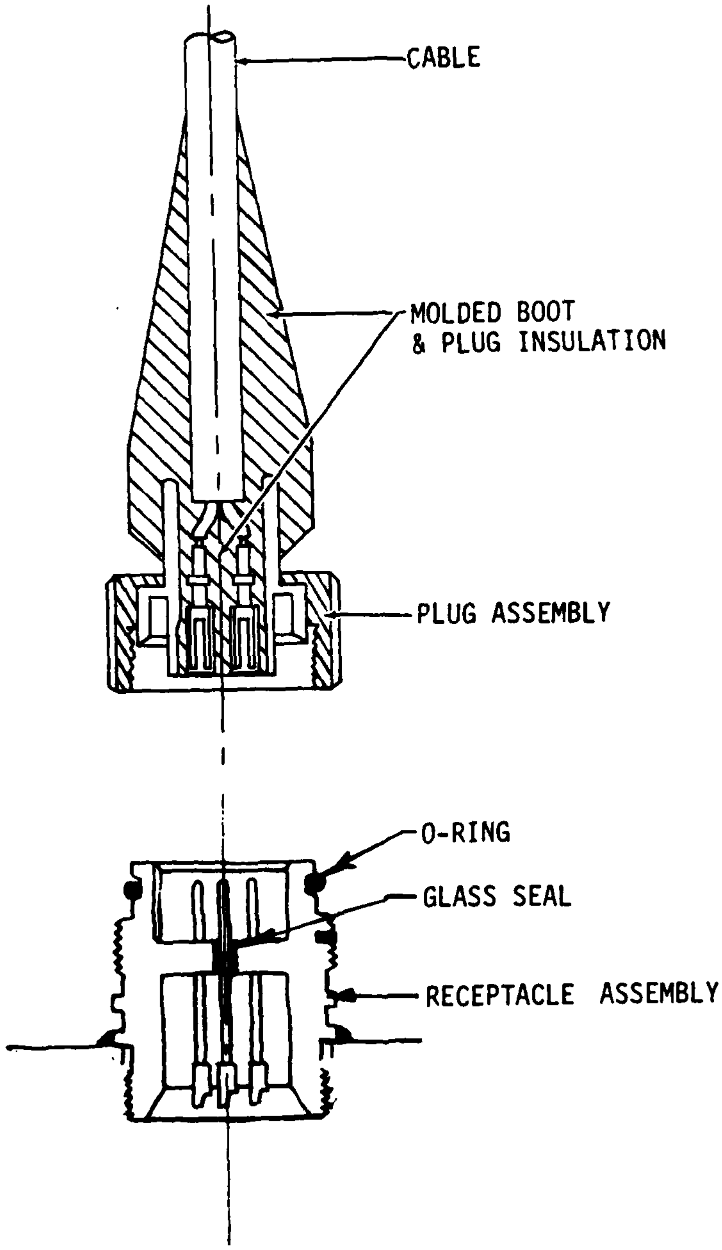


FIGURE 2-10 DOLPHIN GLASS SEALED MIL-C-24231 CONNECTOR

2.9 Field Assembly Connectors

A field assembly connector specification has been prepared by the Naval Underwater Systems Center, New London, Connecticut, for NAVSEA. (See Reference 2-10.) The specification provides design details of field assembly plugs which are primarily used on submarine antenna systems. Most of the plug designs allow mating to the MIL-C-24231 type receptacles. The primary design feature in these plug assemblies is that the outboard cables are sealed to the plug body with a "fat" O-ring gasket in lieu of a molded rubber boot. See Figure 2-11.

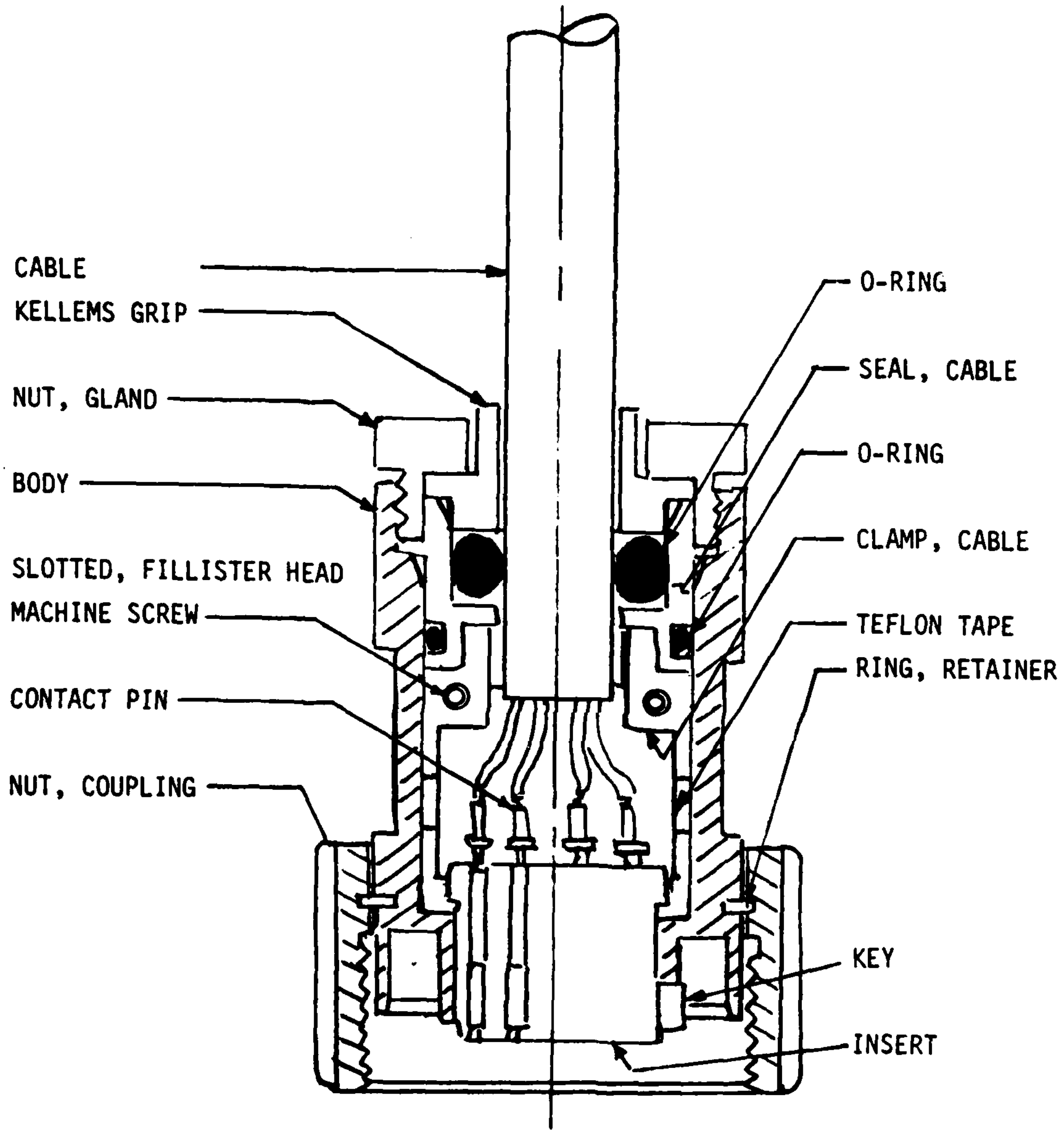


FIGURE 2-11 NUSC FIELD ASSEMBLY CONNECTOR

2.10 NR-1 Connectors

There are approximately 220 outboard cable harnesses on the NR-1. Over 97 percent of the connectors used at each end of the cable harnesses are the MIL-C-24217 type. The remainder are the MIL-C-24231 connector type. The MIL-C-24217 plug connectors are prepotted with polyurethane rubber prior to molding a neoprene rubber boot, per Reference 2-11. See Figure 2-12. The MIL-C-24231 plug assemblies are molded with polyurethane.

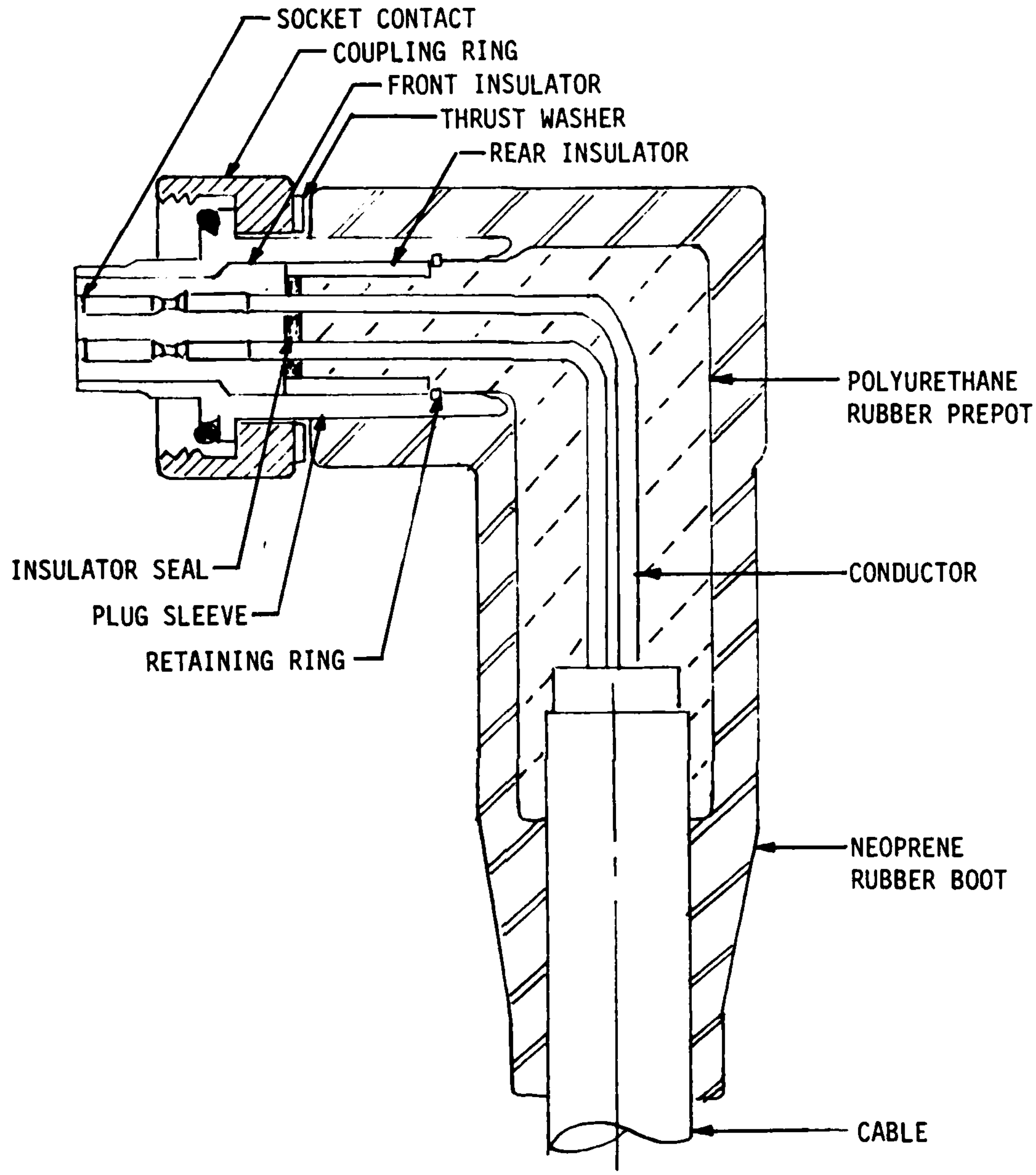


FIGURE 2-12 NR-1 MIL-C-24217 PLUG ASSEMBLY

2.11 Deep-Submergence Rescue Vehicle (DSRV) Connectors

The DSRV outboard connectors are primarily the MIL-C-24217 type. A small number of special aluminum bodied connectors are used as well as a few D. G. O'Brien, Inc., 110 Series Coaxial connector types. The connector plug assemblies which mate to the hull penetrators are also designed specifically for these devices. The DSRV MIL-C-24217 connector plugs are prepotted with an epoxy resin prior to molding the neoprene rubber boot per Reference 2-12.

The DSRV's are currently undergoing a modification to replace the standard neoprene jacketed outboard cables with oil-filled types. As seen in Figure 2-13, the MIL-C-24217 connectors have been redesigned with glass seals to accept oil filled cables. Connector drawings are detailed on NAVSEA drawings 302-2920061, 302-2920062, 320-2920063, 320-2920065, 302-2920066, 302-2920067 and 302-2920071.

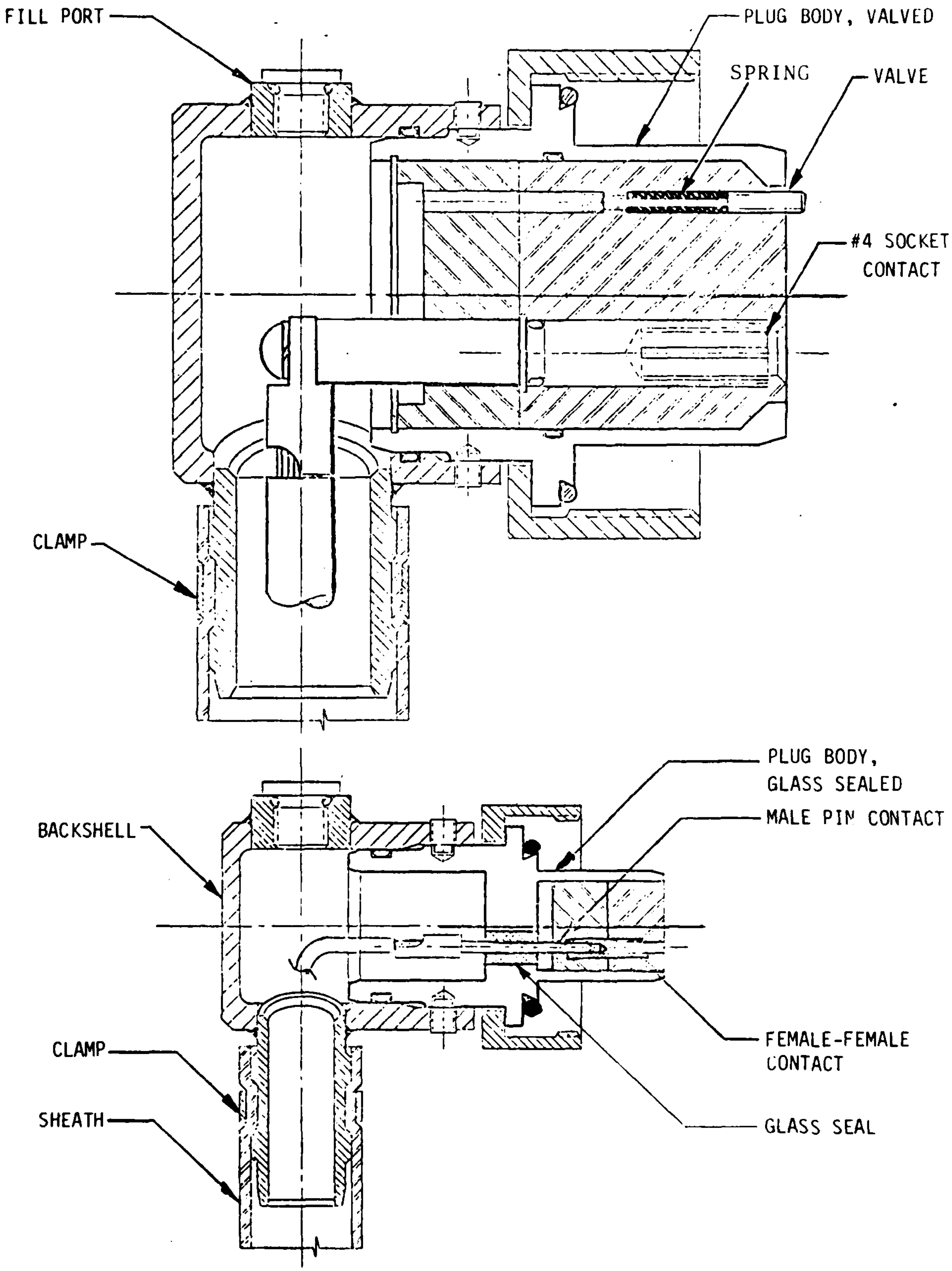


FIGURE 2-13 DSRV OIL FILLED CONNECTORS

2.12 Deep-Submergence Vehicle (DSV) Oil-Filled Connectors

The 20,000 foot DSV, SEA CLIFF, designed at the Mare Island Naval Shipyard provides for the use of oil filled outboard cable assemblies using plugs and receptacles similar to MIL-C-24217. Titanium bodied connectors are used at the hull penetrators and plugs cf the outboard equipment. A typical connector assembly is detailed in Figure 2-14. The design is detailed in Reference 2-13.

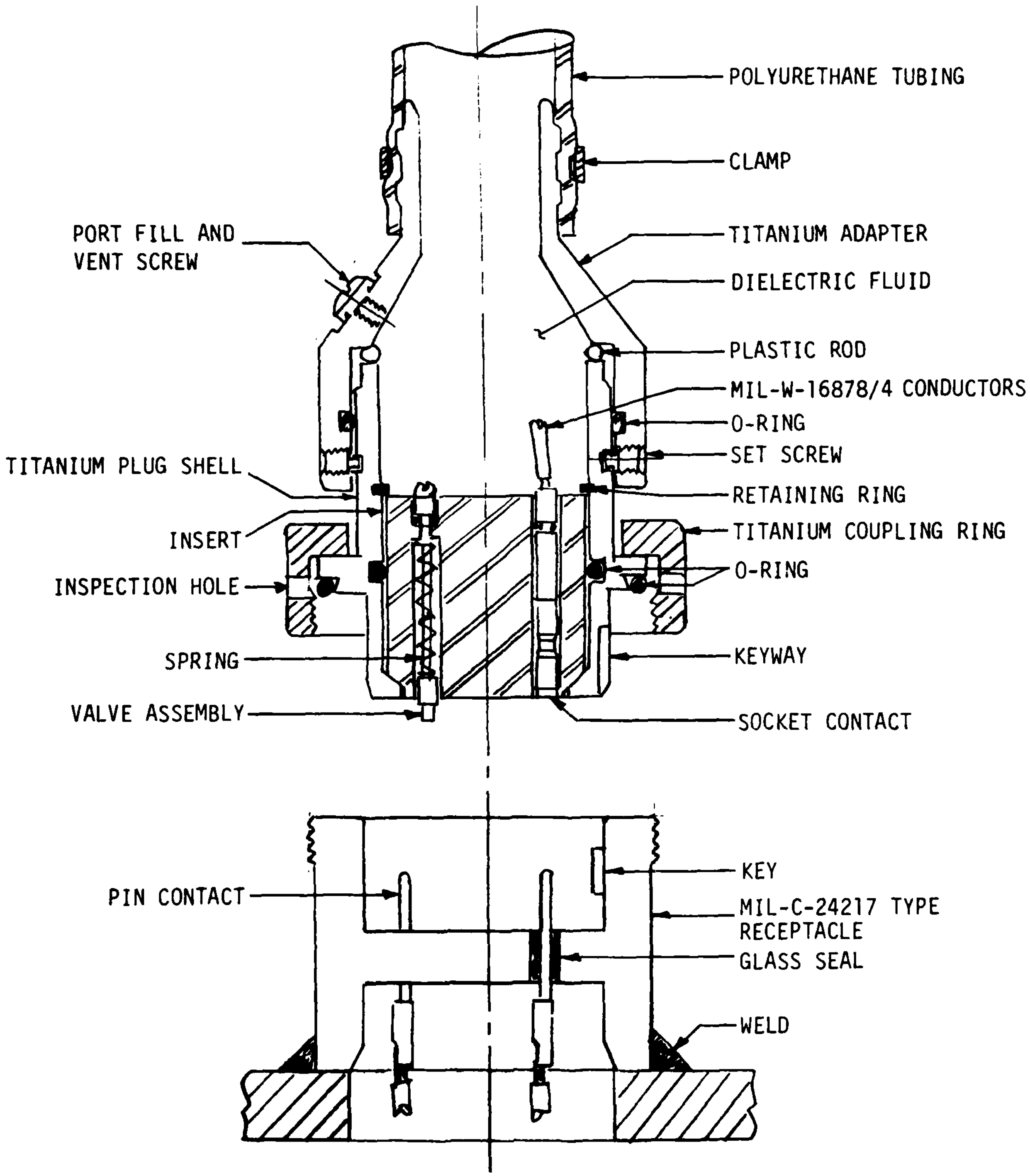


FIGURE 2-14 DSV OIL FILLED CONNECTOR

2.13 The SEA CLIFF - TURTLE Connectors

DSV-4 and 3 (SEA CLIFF AND TURTLE) vehicles presently use outboard cable harness assemblies which are terminated with MIL-C-24217 connectors. The plugs are sealed to the cables with a polyurethane rubber molded boot in accordance with Reference 2-14.

2.14 RAPLOC Wide-Aperture Array Connectors

A wide aperture hydrophone array recently designed by NUSC, New London, Connecticut, for submarines will utilize modified MIL-C-24231 type connectors at the hydrophone and hull penetrator ends of the cable. For this application, the MIL-C-24231 plug has been redesigned to provide a castellated surface at the plug sleeve molded boot bond area. This will provide additional rubber-to-metal bond surface. Four existing 3/8" diameter holes in the plug sleeve have also been eliminated to increase the seawater leakage path at the rubber-to-metal bond interface. A banding clamp has also been added around the amber polyurethane rubber boot to provide a mechanical rubber-to-metal seal. The castellated plug sleeve will aid this sealing process. The plug socket contacts are also bonded to the polyurethane plug insert similar to the TRIDENT connectors. See Figure 2-15, and Electric Boat Division Drawing CPG 1318, Reference 2-15, for design details.

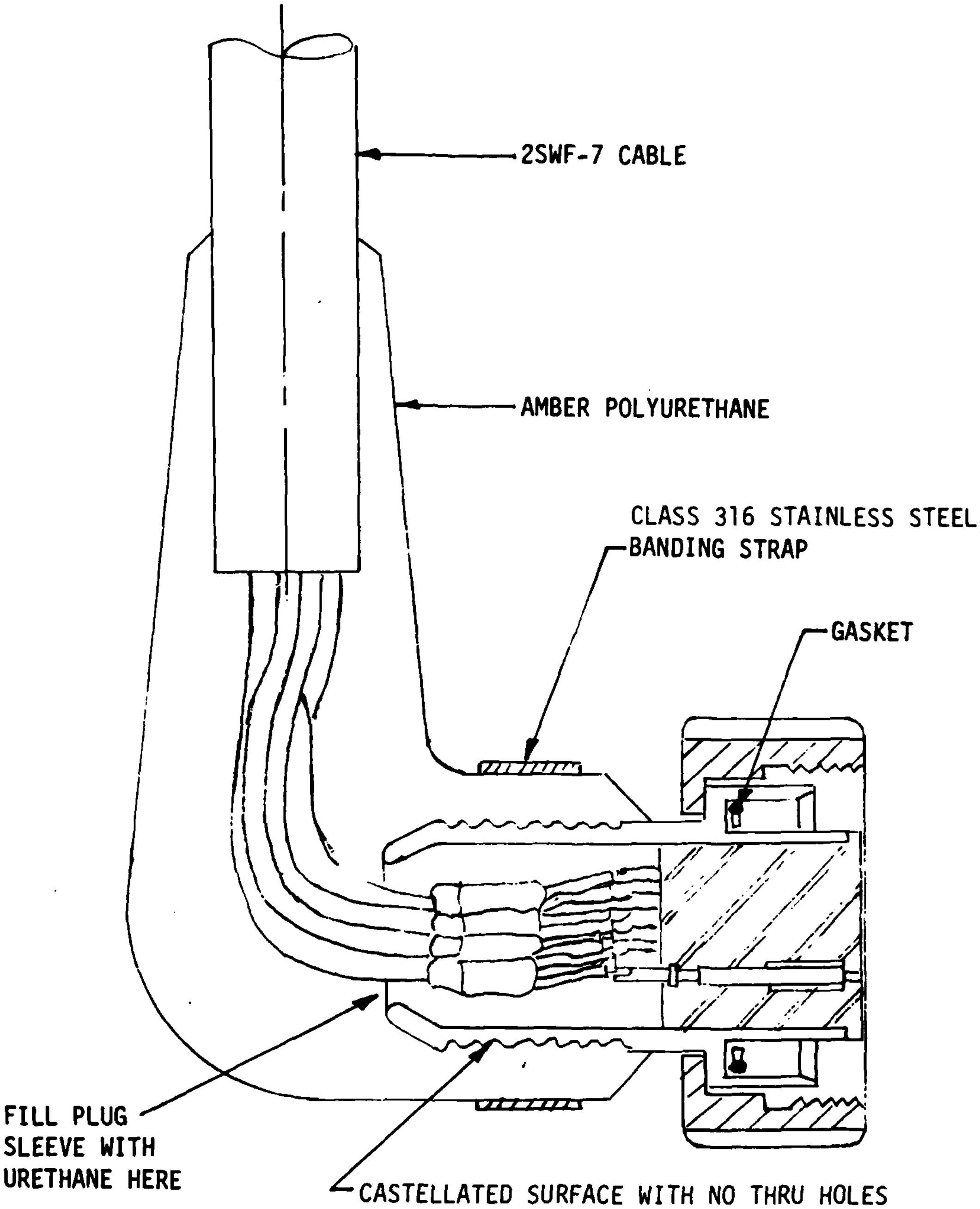


FIGURE 2-15 RAPLOC MIL-C-24231 MODIFIED PLUG ASSEMBLY

2.15 D. G. O'Brien, Inc., 110 Series Coaxial Connectors

D. G. O'Brien, Inc., Seabrook, NH, designed a miniature underwater coaxial connector assembly which is used on a number of Navy applications. The plug and receptacle are fabricated from type 316 stainless steel. The inner and outer contacts located in the receptacle are glass sealed. An inner and outer socket contact is housed in the plug sleeve and retained with a Teflon bushing. Redundant O-ring gaskets located in the plug and receptacle seal the plug to the receptacle. The receptacle is sealed to the component with an O-ring and retained with threads. The plug is designed for molding a rubber boot to the plug sleeve and cable. The design is shown in Figure 2-16. See Reference 2-16 for connector part numbers.

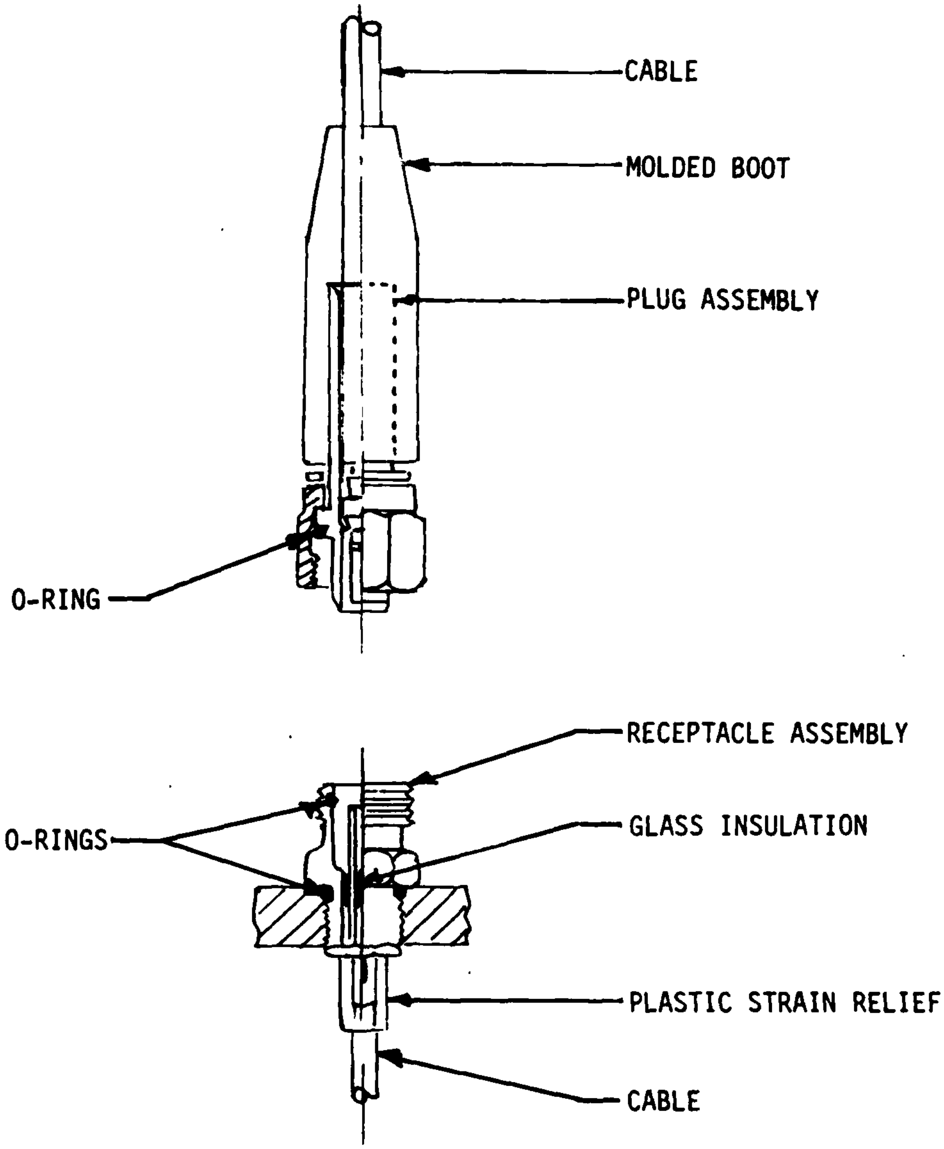


FIGURE 2-16 D.G. O'BRIEN, INC., 110 SERIES COAXIAL CONNECTOR

2.16 Deep Ocean Technology Program (DOT) 20,000-Foot Operating Depth Connectors

One of the many program efforts of the DOT Program involved the design of electrical connectors for deep submergence operating depths. In this program, a number of connectors were designed, fabricated and tested for future deep submergence applications. As seen in Figure 2-17, MIL-C-24217 type connectors were designed to meet the requirements. The plug and receptacle asemblies are Titanium bodied. The plug and receptacles house glass sealed pin contacts. Double ended socket contacts are located in the front end of the plug to allow proper plug-to-receptacle mating. The socket contacts are insulated with silicone rubber. The plug assembly is prepotted with epoxy and housed in an aluminum backshell. A polyurethane rubber boot seals the cable to the plug. The plug is also adaptable to the use of oil filled cables. All other connector design features such as keying and plug-to-receptacle sealing are similar to the MIL-C-24217 connectors. The designs are detailed in Electric Boat Division Specification CPG 1137 , Reference 2-17.

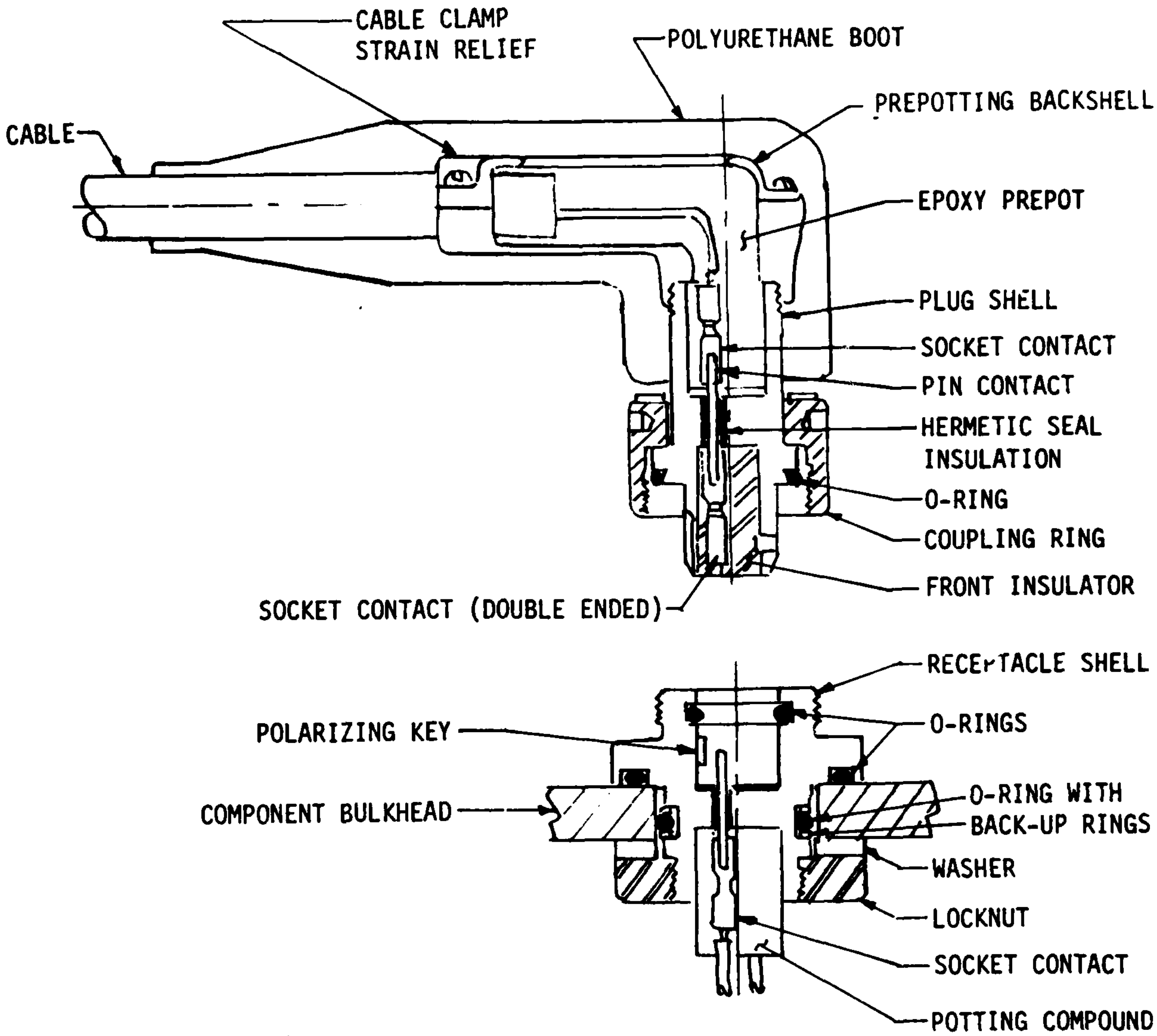


FIGURE 2-17 DOT PROGRAM DSV CONNECTOR

2.17 Pressure-Proof Cable Glands

Cable glands are not considered to be connectors. However, as they have been widely used to terminate electrical cables at sonar system components, they should be noted here. Figure 2-18 depicts a typical cable gland. In this design the outboard cable is sealed to the cable gland with a molded neoprene or polyurethane rubber boot. The inside diameter of the gland is usually chamfered at the outboard end to provide a rubber wedge to prevent cable intrusion into the hydrophone or transducer housing under hydrostatic pressure loading. The cable gland is O-ring sealed to the component housing and is either fastened by bolting or threaded methods. It should be noted in this design that a damaged cable jacket will result in flooding of the hydrophone or transducer. Figure 2-19 details a cable gland design where the cable conductors are provided with a header assembly in the cable gland which seal the conductors. This feature prevents sea-water entry into the outboard component should the cable jacket be damaged in service.

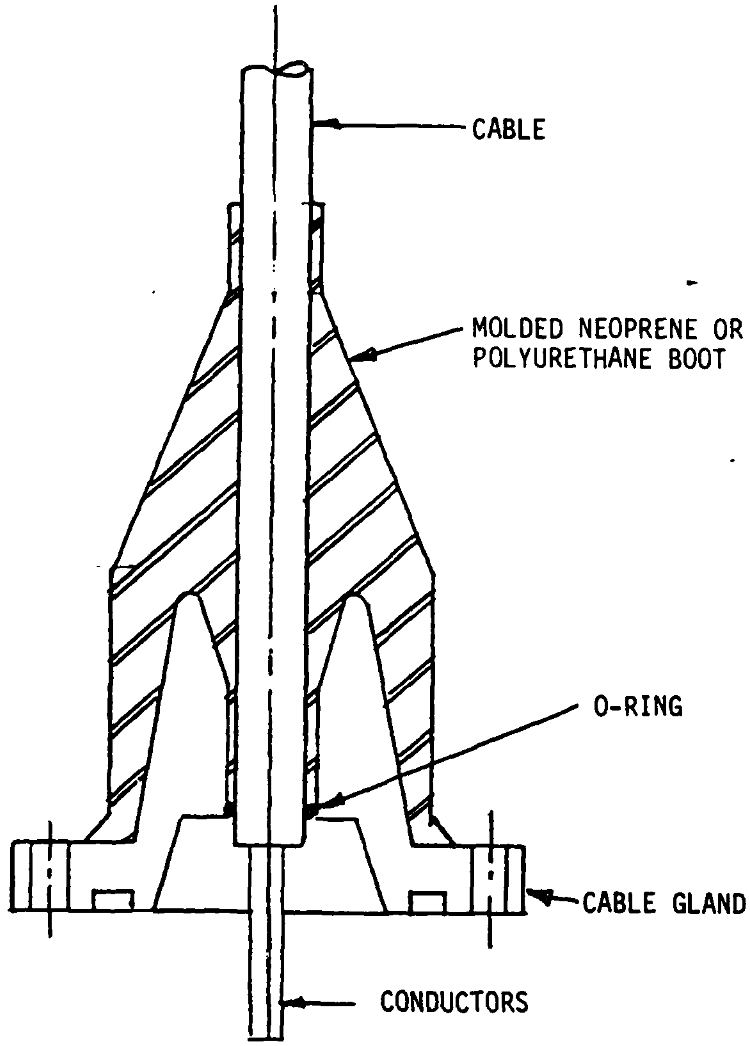


FIGURE 2-18 SONAR SYSTEM COMPONENT CABLE GLAND

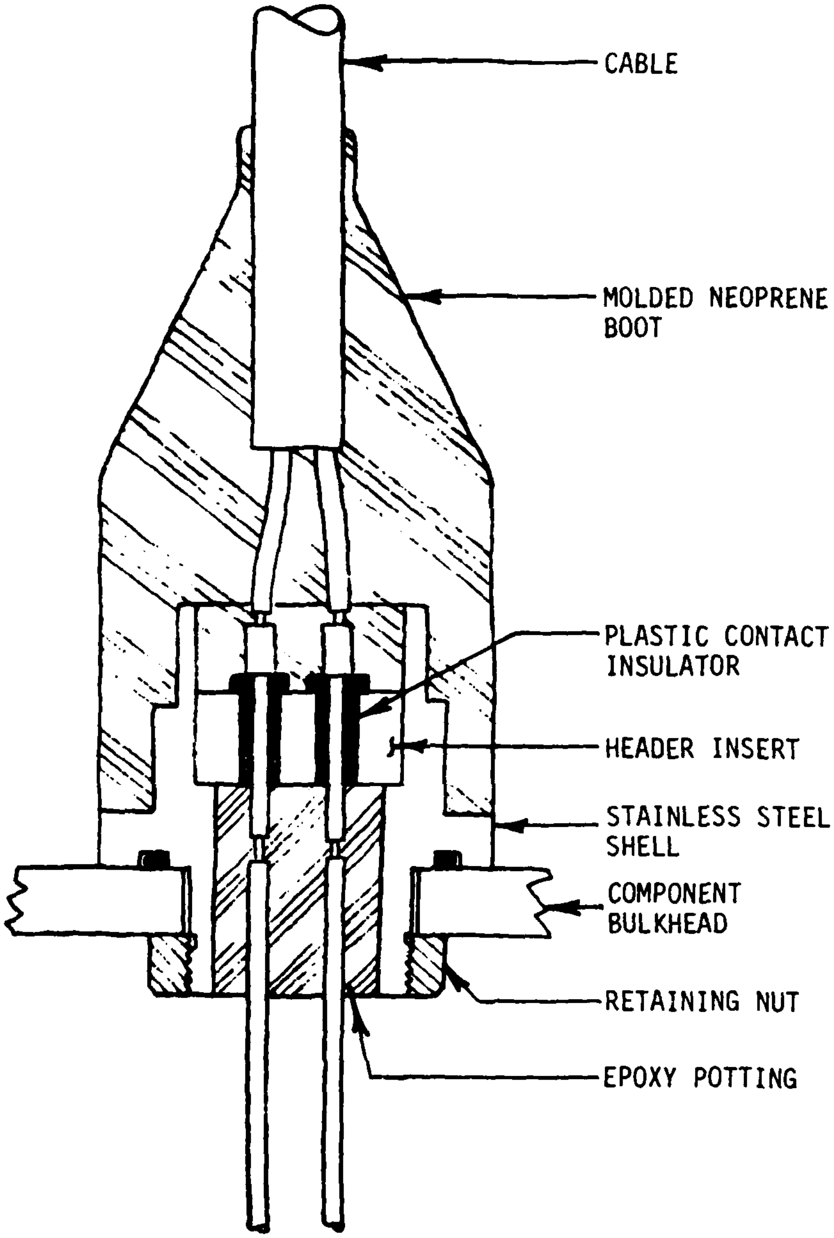


FIGURE 2-19 SONAR SYSTEM COMPONENT CONDUCTOR SEALED CABLE GLAND

2.18 Cable Stuffing Tubes

Cable stuffing tubes cannot be considered as connector designs but should be noted here as they were the first cable seals to be used at pressure hulls and outboard components. The basic cable stuffing tube design is shown in Figure 2-20. The cable enters a housing which is usually welded or brazed to the component case. The cable is sealed to the stuffing tube housing with a rubber grommet which fits closely over the cable jacket. The grommet is pressurized to the cable and housing with a gland nut to provide a seal. The design has been improved with the addition of a spring washer located between the gland nut and metal washer to assure constant pressurization of the grommet. With the advent of deeper diving vehicles and submarines, this cable seal design has been replaced with electrical connectors. References 2-18 and 2-19 provide details of typical cable stuffing tube designs. Cable stuffing tubes are detailed in MIL-S-24235 (SHIPS).

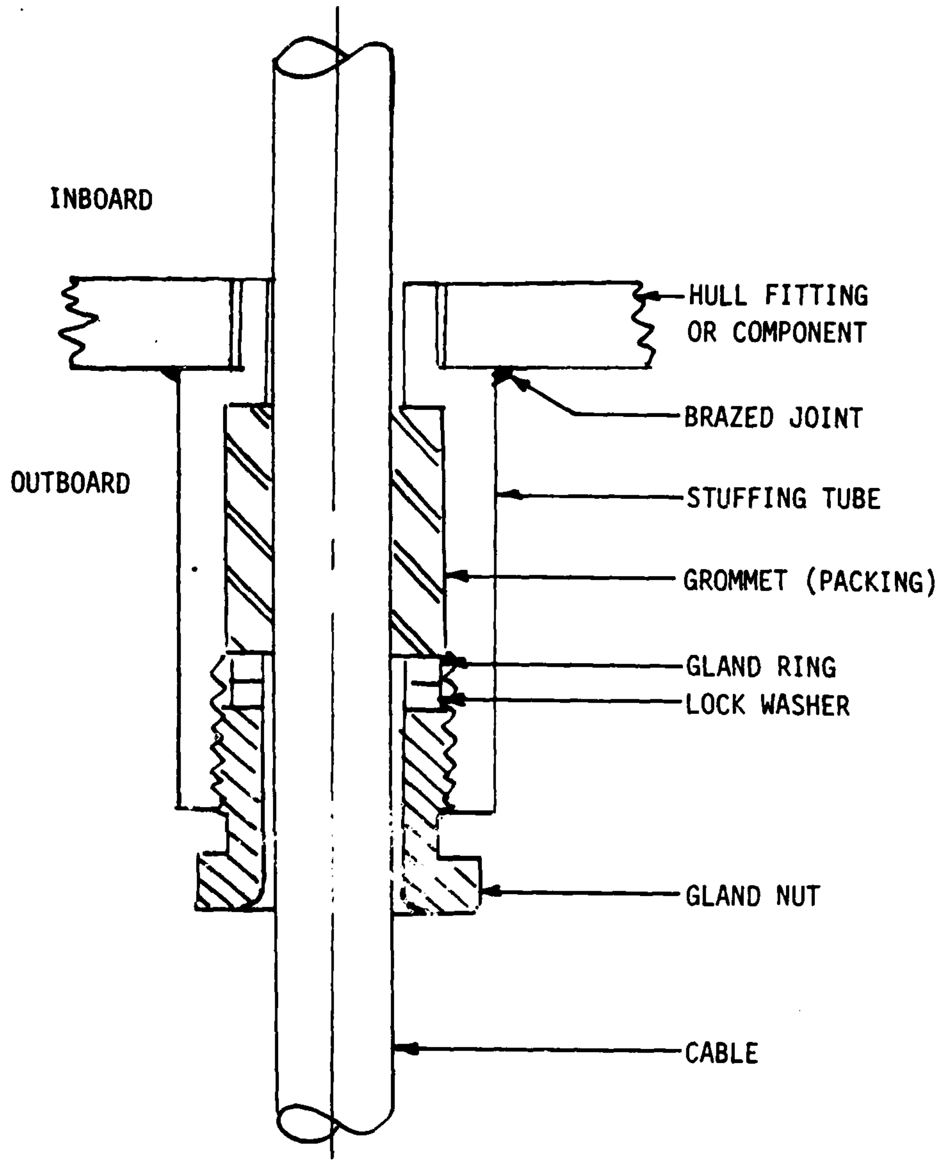


FIGURE 2-20 CABLE STUFFING TUBE

2.19 MIL-C-22249 Connectors

These connectors have been designed for penetrating the missile tubes of fleet ballistic submarines. Typical connector (a penetrator) assembly is shown in Figure 2-21 and is detailed in Reference 2-20. The connector design is comprised of a union style (double ended) receptacle assembly housed in a missile tube insert. The receptacle is a glass sealed type similar to the MIL-C-24217. Plugs are located on both sides of the receptacle. The plugs and receptacles are fabricated from type 316 stainless steel. The coupling rings are nickel aluminum bronze. Neoprene or polyurethane rubber is used to seal the plugs to the cables. These connectors provide an ideal interface between the missile vendor and the submarine shipbuilder as the missile vendor provides the connectorized cable assembly within the missile tube and the shipbuilder provides the pressure-proof receptacle and the compartment side plug-cable assembly.

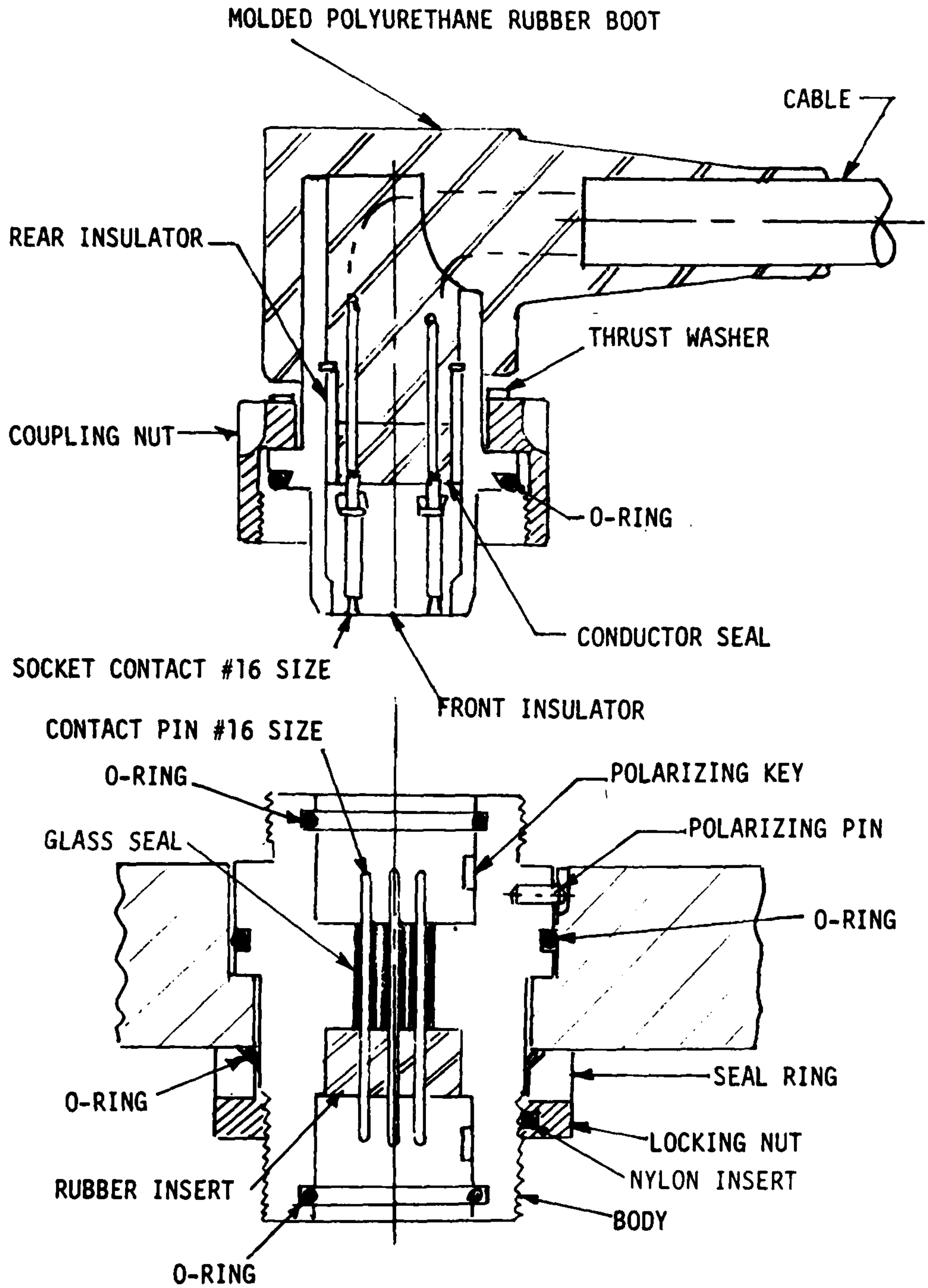


FIGURE 2-21 MIL-C-22249 CONNECTOR

2.20 Naval Laboratory Connectors

A number of commercial underwater connectors are used at various Navy laboratories in component research and test equipment applications. These connectors include designs offered by the following companies whose addresses are supplied in Appendix C.

Boston Insulated Wire & Cable Company

Brantner Associates

Burton Electrical Engineering

Celmark Engineering Co.

Crouse-Hinds Electro

Envirocon Division
Rochester Company

Glenair, Inc.

Hermetic Seal Corporation

Joy Manufacturing Company

Kemlon Products and Development Company

Kintec, Inc.

Mecca Cable and Service Company

Rowe Industries

Vector Cable Company

2.21 Underwater Make-and-Break Connectors

Underwater make and break connectors are not presently in wide use on Navy vehicles. They are used, however, in small quantities on a number of research vehicles. References 2-21 through 2-27 provide information regarding the connector types available and the design work being carried on in this area.

REFERENCES

2-1 MIL-C-24231, "Connectors, Plugs, Receptacles, Adapters, Hull Inserts and Hull Insert Plugs, Pressure-Proof".

2-2 General Electric Company, Syracuse, New York, Drawings 77D603108, "Cable, Trunk Outline" and Drawing 77D6033109, "Cable, Element, Outline".

2-3 MIL-C-24217, "Connectors, Electrical, Deep Submergence, Submarines".

2-4 NAVSEA Drawing 815-1197170, "Hermetically Sealed Connectors for 3, 4 and 5 No. 12 and 8 No. 16 Pins".

2-5 Electric Boat Division Specification CPG 1027, "Connector, Plug and In Line Receptacle, Molded, Electrical 3, 4, 7, 9, 14, 24, 30 and 40 Conductor, Pressure-Proof".

2-6 D. G. O'Brien, Inc., "C17D5005G, "Glass Sealed Straight Plug With Tail piece (Outline Dimensions)".

2-7 Electric Boat Division Specification CPG 1265, "Cable Assembly, Pressure-Proof, Polyethylene Molded, for Submarines", December 8, 1977.

2-8 MIL-C-XXXXX, "Connectors, Electrical, Miniature, Pressure-Proof", (PROPOSED).

REFERENCES

(Continued)

2-9 NAVSEA Drawing No. 5935-DMD-0923, "3 Pin Plug Assembly".

2-10 Naval Underwater Systems Center, New London, CT, Specification NUSC-C-342/9235/516, "Connector, Pressure-Proof, Field Assembly, Multi Conductor and Radio Frequency", 10 March, 1980.

2-11 NAVSEA Drawing NR-1-302-2663185, "NR-1 Wiring and Molding, Testing, Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators," Revision "H".

2-12 Lockheed Specification RV-S-0104, "Fabrication of Submersible Electrical Cable Assemblies".

2-13 NAVSEA Specification DSV-4-304-5155928, "General Specification for Connectors, Oil-Filled for Deep Submergence Vehicle Cabling".

2-14 NAVSEA S9074-AA-MMO-010/DSV-3,4, "Technical Manual - Fabrication, Installation, Maintenance and Repair - Outboard Cable Harness Assembly TURTLE (DSV-3), SEA CLIFF (DSV-4)", January, 1978.

2-15 Electric Boat Division Drawing CPG 1319/1, "Outboard Electrical Plug Assembly - 15 Contact for RAPLOC Program".

REFERENCES

(Continued)

2-16 D. G. O'Brien, Inc., 110 Series Miniature High-Pressure Coaxial Connector. D. G. O'Brien, Inc., Catalog, Seabrook, NH, 03874.

2-17 Electric Boat Division Specification CPG 1137, "Military Specification, Connectors, Electric, Deep Submergence".

2-18 NAVSEA Drawing S-5100-L, "Stuffing Tubes, Type 46-1 Electrical Cables - Submarine".

2-19 NAVSEA Drawing 9000-S6202-1197101, "Stuffing Tube Assembly.

2-20 MIL-C-22249, "Connector Sets, Electrical, Hermetically Sealed Submarine".

2-21 Nelson, A. L., "Deep Sea Electrical Connectors and Feed - Through Insulators for Packaging Electronics", National Electronic Packaging and Production Conference, June 9, 1965, Long Beach, CA.

2-22 Tuttle, J.D., "Underwater Electrical Integrity", Marine Technology Society Annual Meeting.

REFERENCES

(Continued)

2-23 Wilson, J.V., "Applying Wet Connectors", Ocean Industry, October, 1978.

2-24 Wilson, J.V., "Underwater Mateable Electromechanical Connectors for Power and Signal Cables", Offshore Technology Conference, Dallas, Texas. OTC Paper No. 2581.

2-25 Wilson, J.V., "Technical Report - Coaxial Underwater Mateable Connectors - A New Technology for Seafloor Structure Applications", Civil Engineering Laboratory, Port Hueneme, CA 93043, Report No. R875, September, 1979.

2-26 McCartney, J.F. & Wilson, J.V., "Development of an Underwater Mateable High-Power Cable Connector", Offshore Technology Conference Paper No. OTC 1976, Houston, Texas, May 6-8, 1974.

2-27 Haworth, R.F., "Feasibility Study of Using Underwater Make and Break Connectors on the NR-1", Electric Boat Division Report No. U 443-78-079, December, 1978. Contract N00024-78-C-7003, Task 192.

SECTION 3

NAVSEA APPROVED OUTBOARD CABLES

LIST OF FIGURES

LIST OF TABLES

3.1 Introduction

Most sonar system electrical cables located outboard of the pressure hull on attack and fleet ballistic missile submarines are the "watertight" (waterblocked) types specified in MIL-C-915, Reference 3-1. A smaller number of coaxial type cables have also been used. These are detailed in MIL-C-17, Reference 3-2. Also, a number of outboard cables have been designed for use on the TRIDENT submarines. These are detailed in Electric Boat Specification sheets CPG 1000. Finally, outboard cables have been designed by the hydrophone and transducer manufacturers. Table 3-1 provides a listing of military specification data for outboard cables. The following discussion describes the outboard cables presently approved by the U.S. Navy.

TABLE 3-1

Outboard Cable Specification Data

Cable Type	Insulation Resistance (1) (megohms/1000 ft minimum)	Rated Voltage (VAC, RMS)	Conductor Resistance (maximum/ohms/ 1000 ft)	Mutual Capacitance (picofarads/ ft at 1 KHz maximum)	Weight In Air (lbs/ft)	Minimum Bend Radius (Inches)	Breaking (3) Strength (lbs/N)
DSS-2	500	600	6.64	45	.120	1.0	139/620
DSS-3	500	600	4.15	45	.160	1.5	256/1140
DSS-4	500	600	2.57	45	.180	1.5	346/1540
TSS-2	500	600	6.64	--	.140	1.0	
TSS-3	500	600	4.15	--	.180	1.5	
TSS-4	500	600	2.57	--	.200	1.5	
FSS-2	500	600	6.64	--	.180	1.5	297/1320
FSS-3	500	600	4.15	--	.210	1.5	
FSS-4	500	600	2.57	--	.240	2.0	
7SS-2	500	600	6.64	--	.185	1.5	
2SWF-3	---	2000 (2)	17.71	30	.204	2.0	
2SWF-4	---	2000 (2)	17.71	30	.211	2.0	
2SWF-7	---	2000 (2)	17.71	30	.366	2.5	
S2S	500	1500 (2)	6.64	37 ± 1	1.000	3.0	
1SWF-2	---	2000 (2)		28	.188	2.0	
MWF-7	---	600	7.47	--	.145	1.5	
MWF-10	---	600	7.47	--	.230	2.0	
MWF-14	---	600	7.47	--	.250	2.0	
MWF-19	---	600	7.47	--	.350	2.5	
MWF-24	---	600	7.47	--	.430	2.5	
MWF-30	---	600	7.47	--	.550	3.0	
MWF-37	---	600	7.47	--	.680	3.5	
TSP-11	100	300	17.06	--	.275	4.5	
TSP-31	100	300	17.06	--	.611	6.5	
DSWS-4	100	10000 (2)	2.57	40 ± 10	----	3.0	

(1) Conductor to conductor; (2) Test Voltage. (3) Reference 3-7

3.2 MIL-C-915 Cables

The MIL-C-915 cables approved by the Navy for use outboard on submarines are listed and detailed in Table 3-2. Not all of these cables are used on sonar systems. Table 3-3 is a listing of those cables which have been used in conjunction with various sonar systems. (See table 1-1.)

3.2.1 <u>SS Type Cables</u> - The DSS, TSS, FSS, 7SS and DSWS type cables are constructed as depicted in Figure 3-1. The conductors are tin coated copper covered with a synthetic rubber insulation. The conductor strands are filled with a rubber sealer. The conductors are twisted together and the conductor interstices are filled with a synthetic rubber belt. A shielding braid comprised of number 34 AWG tin coated copper wire is then applied over the belt. The cable jacket is an extruded arctic polychloroprene (Neoprene); or chlorosulfonated polyethylene (HYPALON). In some constructions, an inner layer of butyl rubber is provided and is bonded to the outer jacket. The butyl rubber provides long term insulation resistance of the braided shield to the sea water environment. The mutual capacitance of the DSS-3 cable is 45 picofarads maximum per foot at 1 kilohertz. The measurement is made with the black conductor connected to the shield at one end of the cable specimen. The mutual capacitance of the DSWS cable is 40 ± 10 picofarads per foot at 1 kilohertz maximum.

TABLE 3-2

MIL-C-915 Outboard Cable Construction Details

Cable Type	No. Of Conductors	Shields	Type Of Conductor	Conductor Diameter (Inches)	Conductor Insulation Diameter (Minimum)	Cable Diameter (Inches)
DSS-2	2	1	7/.016	.048	.088	.370/.390
DSS-3	2	1	7/.020	.060	.110	.480/.500
DSS-4	2	1	7/.025	.076	.126	.480/.500
TSS-2	3	1	7/.016	.048	.088	.385/.400
TSS-3	3	1	7/.020	.060	.110	.480/.500
TSS-4	3	1	7/.025	.076	.126	.480/.500
FSS-2	4	1	7/.016	.048	.088	.480/.500
FSS-3	4	1	7/.020	.060	.110	.480/.500
FSS-4	4	1	7/.025	.076	.126	.600/.625
7SS-2	7	1	7/.016	.048	.088	.600/.625
MSS-6	2 Pairs 2 Ind.	2	7/.013	.038	.068	.470/.490
2SWF-3	3 Pairs	3	7/.010	.030	.050	.600/.625
2SWF-4	4 Pairs	4	7/.010	.030	.050	.600/.625
2SWF-7	7 Pairs	7	7/.010	.030	.050	.780/.815
S2S	1	2	7/.016	.048	.068	.480/.500
1SWF-2	1 Pair	1	7/.010	.030	.050	.600/.625
MWF-7	7	-	7/.0152	.046	.113	.480/.500
MWF-10	10	-	7/.0152	.046	.113	.605/.635
MWF-14	14	-	7/.0152	.046	.113	.605/.635
MWF-19	19	-	7/.0152	.046	.113	.710/.745
MWF-24	24	-	7/.0152	.046	.113	.800/.836
MWF-30	30	-	7/.0152	.046	.113	.905/.945
MWF-37	37	-	7/.0152	.046	.113	1.005/1.045
TSP-11	11 Pairs	-	7/.010	.030	.060	.735 Max.
TSP-31	31 Pairs	-	7/.010	.030	.060	1.062 Max.
DSWS-4	2	1	7/.025	.076	.222	.770/.800

TABLE 3-3

MIL-C-915 Outboard Cables In Use On Sonar Systems

Cable Type	MIL-C-915 Specification Sheet
DSS-2	MIL-C-915/8
DSS-3	MIL-C-915/8
DSS-4	MIL-C-915/8
FSS-2	MIL-C-915/8
7SS-2	MIL-C-915/8
DSWS-4	MIL-C-915/7
2SWF-3	MIL-C-915/48
2SWF-4	MIL-C-915/48
2SWF-7	MIL-C-915/48
S2S	MIL-C-915/61
TSP-11	MIL-C-915/22
TSP-31	MIL-C-915/22

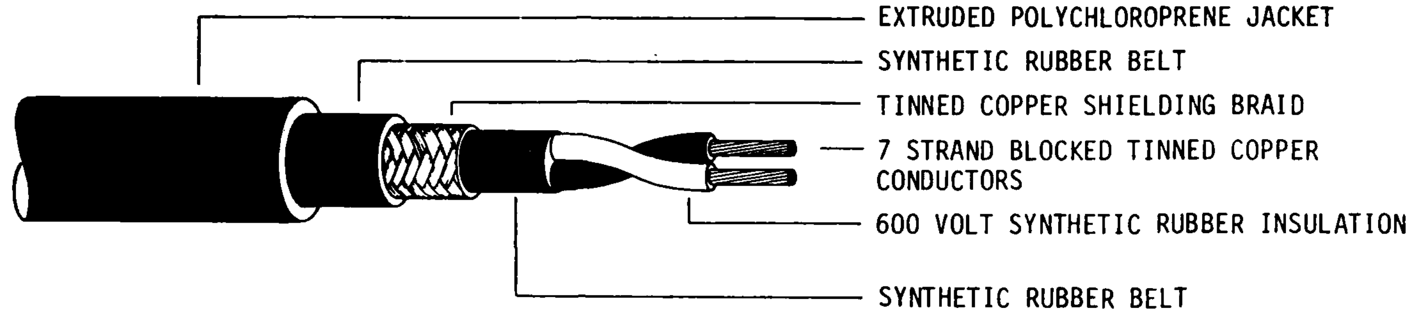


FIGURE 3-1. MIL-C-915 SS TYPE CABLE CONSTRUCTION

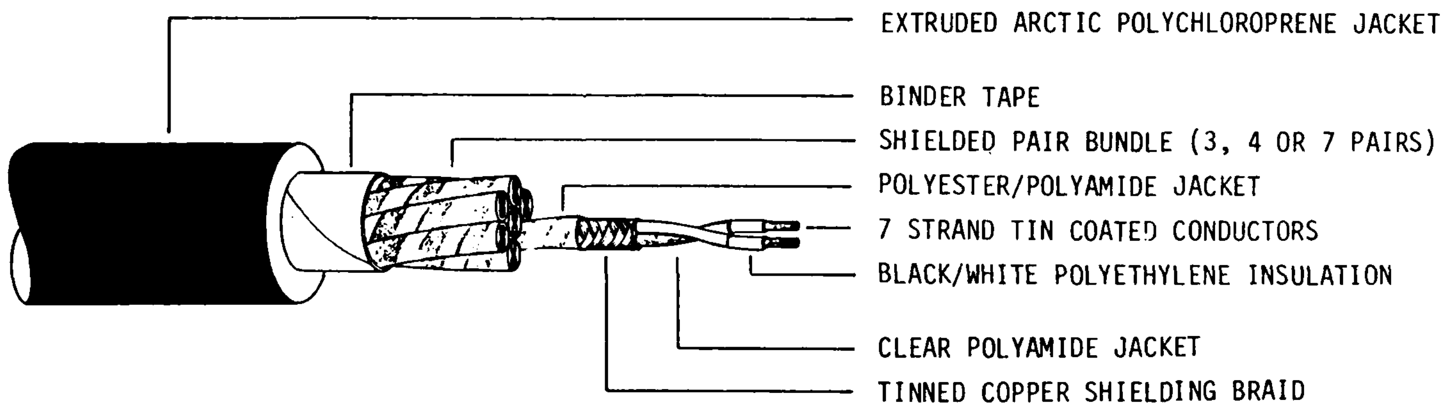


FIGURE 3-2. MIL-C-915 2SWF TYPE CABLE CONSTRUCTION

3.2.2 2SWF Type Cables - 2SWF-3, 4 and 7 cables are constructed as depicted in Figure 3-2. The conductors are tin coated copper. The conductor strands valleys are filled with a sealer material. Polyethylene is used to insulate the conductors. The insulation is covered with a clear polyamide (NYLON) jacket. The conductors are twisted together and the valleys are filled with a sealer. A shielding braid comprised of 34 or 36 AWG tin coated copper wires is then applied over the two twisted conductors. Polyester (MYLAR) or polyester-polyamide tapes are used to insulate the shield. The 3, 4 or 7 shielded pairs are bundled together and covered with a synthetic rubber binder tape. The cable jacket is an arctic polychloroprene (Neoprene). The mutual capacitance of the 2SWF cables is 30 picofarads per foot maximum at 1 kilohertz. The characteristic impedance is 75 ± 5 ohms at 1 megahertz. The attenuation is 3 decibels maximum per 100 foot at 3 megahertz.

3.2.3 1SWF-2 Cables - The 1SWF-2 cable is constructed as shown in Figure 3-3. The conductors are uncoated copper. The conductor strand valleys are filled with a filler material. Polyethylene is used to insulate the conductors. Each conductor is covered with a number 36 AWG uncoated copper braided shield A polyester (MYLAR) tape covers each braided shield. The conductors are twisted together and the valleys are filled with a sealer. The conductor pair is then covered with a binder tape. The cable is jacketed with an arctic polychloroprene (Neoprene) rubber. The capacitance is 28 picofarads maximum per foot at 1 kilohertz. The characteristic impedance is 61 $\pm$ 3 ohms at 1 megahertz.

3.2.4 MWF Type Cables - The MWF type cables are fabricated as shown in Figure 3-4. The conductors are tin coated copper. The conductor strands are filled with a filler material. Synthetic rubber or cross linked polyethylene is used to insulate the conductors. A thin layer of polyamide (Nylon) insulation covers the primary conductor insulation. The required number of conductors are cabled together. The valleys are filled with a rubber sealer. The conductors are then covered with a binder tape. The cable is jacketed with an arctic polychloroprene (Neoprene) jacket.

3.2.5 S2S Cables - The S2S cable is manufactured as depicted in Figure 3-5. The copper conductor is coated with tin. The conductor strands interstices are filled with a sealant. The conductor is insulated with a cross-linked thermosetting polyethylene insulation. A number 34 AWG braided coated copper shield is applied over the conductor. This is followed by a synthetic rubber braid insulation. A braid shield of .006" copper clad steel wires is then applied over the first braid insulation. This braid is then jacketed with a two layer jacket with a nylon reinforcing braid applied between the layers. The first layer is a synthetic rubber and the second or outer layer is an arctic neoprene. The inner and outer layers are bonded together. The capacitance is 37 $\pm$ 1 picofarads per foot maximum at 1 kilohertz.

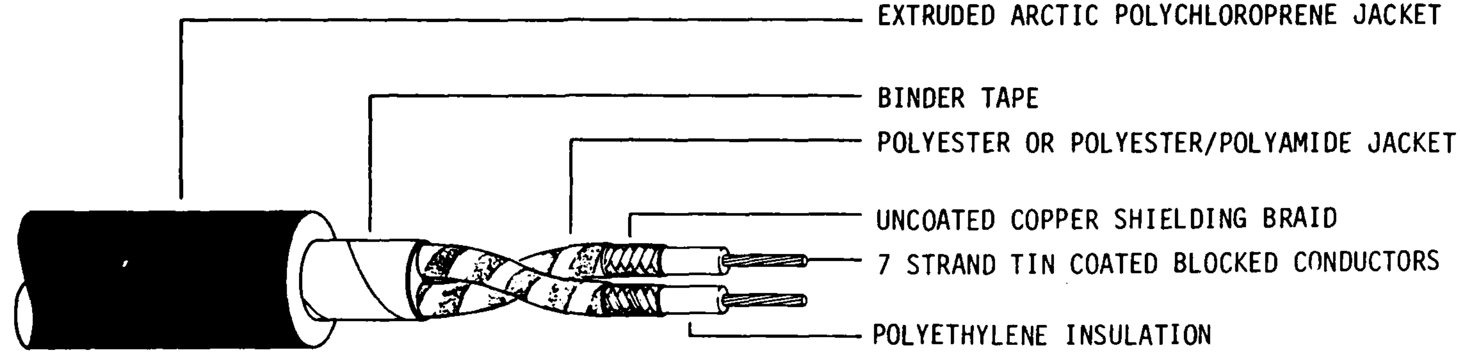


FIGURE 3-3. MIL-C-915 1SWF-2 CABLE CONSTRUCTION

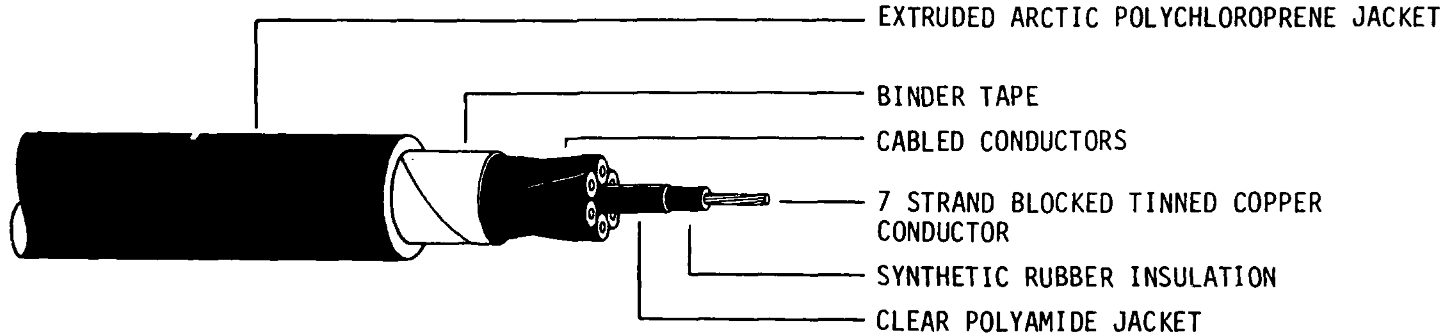


FIGURE 3-4. MIL-C-915 MWF TYPE CABLE CONSTRUCTION

3.2.6 <u>2SWF-20 Cables</u> - This cable was designed by the Naval Underwater Systems Center (NUSC), New London, Ct. for use on the STASS system. The cable is basically a larger size version of the standard 2SWF cables described in paragraph 3.2.2. The cable consists of 20 shielded twisted pairs layed up as follows; a rubber core member; 7 pairs; 13 pairs and a neoprene cable jacket with an approximate 1-1/4 inch outside diameter. The cable construction is noted on NUSC drawing number 01589D1 - and is titled "Stass - Hull to Two Point Interconnecting Cable". The cable has been fabricated by RIW Cable Systems, Inc.

3.2.7 <u>DSU Cables</u> - DSU type cables have been developed by sonar transducer manufacturers and David W. Taylor Naval Ship Research and Development Center, DTNSRDC, Annapolis, MD, cable engineers where the need for DSS-2 and DSS-3 cables without braided shield is desired. A DSU-2 cable design is used on the surface ship "eight to one" cable harness design. The cable is basically a DSS-2 cable construction without the braided shield. This construction allows a slightly thicker neoprene cable jacket (.080 inch minimum wall) and deletes the need for a butyl rubber jacket under the neoprene. The butyl rubber is used to maintain high insulation resistance between the shield and water. A DSU-3 cable is being tested by DTNSRDC to replace the DSS-3 cable in a number of sonar system applications. On these designs the braided shield is being replaced by a rayon or dacron strength member.

3.2.8 <u>9SU-2 Cables</u> - The 9SU-2 cable has been designed for use on the SQS-23 sonar system. The cable is a nine twisted pair construction. The conductor diameter is .048 inches (7 strands of

.016 inch wire) and is insulated with a minimum thickness of .020 inches of synthetic rubber. This insulation is jacketed with .003 inches of extruded nylon. The interstices of the twisted pairs, and conductor strands are filled with a rubber compound to provide a watertight internal cable construction. The cable is jacketed with polychloroprene rubber to an outside diameter of .930 to .960 inches.

3.2.9 Butyl Jacketed DSS-3 Type Cable - This cable, designed by the Naval Weapons Support Center, Crane, Indiana, is used on the AN/BQR-21 sonar system. The cable construction is basically a DSS-3 type except the shielding braid is deleted and the DSS-3 arctic neoprene jacket is replaced with a butyl rubber jacket. The cable has a 1 inch minimum bend radius. The capacitance between the two conductors is 20 $\pm$ 10 picofarads per foot. The cable construction is detailed on NAVSEA drawing 80064-4551225.

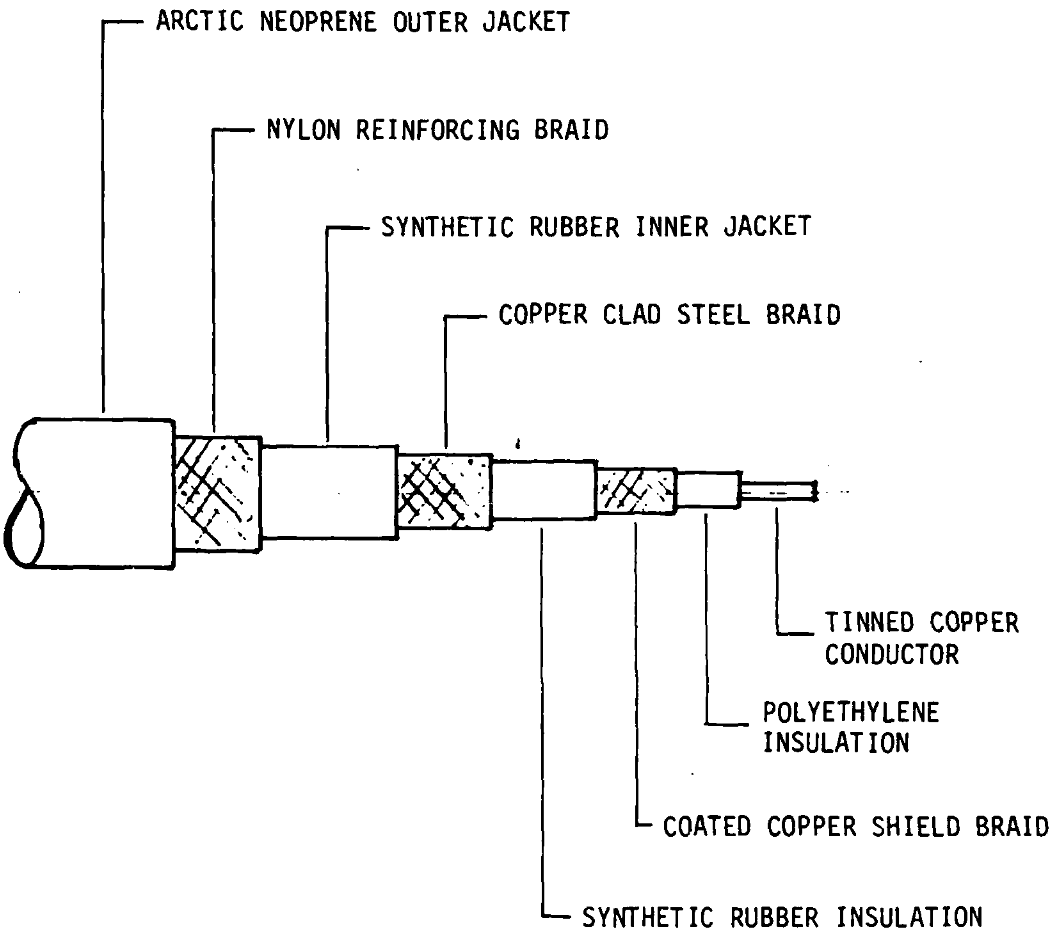


FIGURE 3-5. MIL-C-915 S2S CABLE CONSTRUCTION

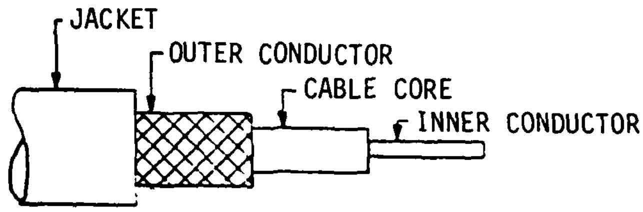
3.3 MIL-C-17 Coaxial Cables

The MIL-C-17 cables approved for submarine use outboard on sonar systems are listed in Table 3-4. Figures 3-6 through 3-8 depict these constructions. Basically, these coaxial cable constructions consist of a tinned copper inner conductor; a polyethylene cable core; a braided tinned or bare copper wire outer conductor; and a polyvinyl chloride plastic jacket. As seen in Figures 3-6 through 3-8, there are slight differences in the cable constructions from cable to cable. Table 3-5 provides construction details for the MIL-C-17 cables used outboard on sonar systems.

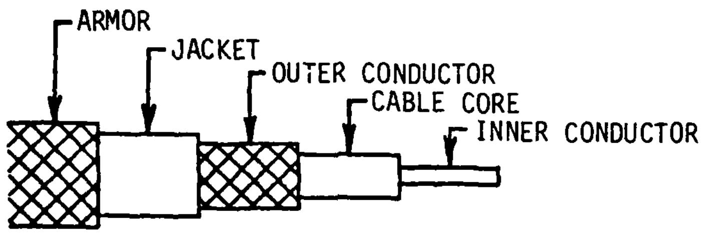
TABLE 3-4

MIL-C-17 Coaxial Cables In Use On
Sonar Systems

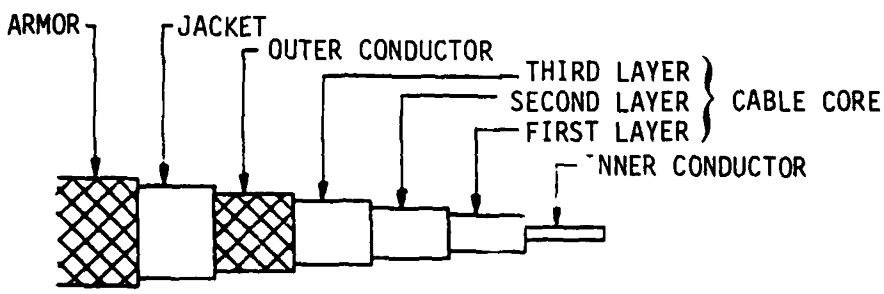
Cable Type	MIL-C-17 Specification Sheet	IMPEDANCE (Ohms)	ATTENUATION db/100 ft MAX at 400 MHz
RG-8/U	MIL-C-17/3	52 ± 2	6.0
RG-12A/U	MIL-C-17/7	75 ± 3	5.2
RG-27/U	MIL-C-17/22	48 ± 4	0.7 (at 1 MHz)
RG-28B/U	MIL-C-17/23	48 ± 4	0.7 (at 1 MHz)
RG-58A/U	MIL-C-17/28	50 ± 2	14.0
RG-59/U	MIL-C-17/29	75 ± 3	9.0
RG-64A/U	MIL-C-17/33	48 ± 4	0.7 (at 1 MHz)
RG-130/U	MIL-C-17/56	95 ±5	8.8



CABLE, RADIO FREQUENCY, COAXIAL, RG-8A/U

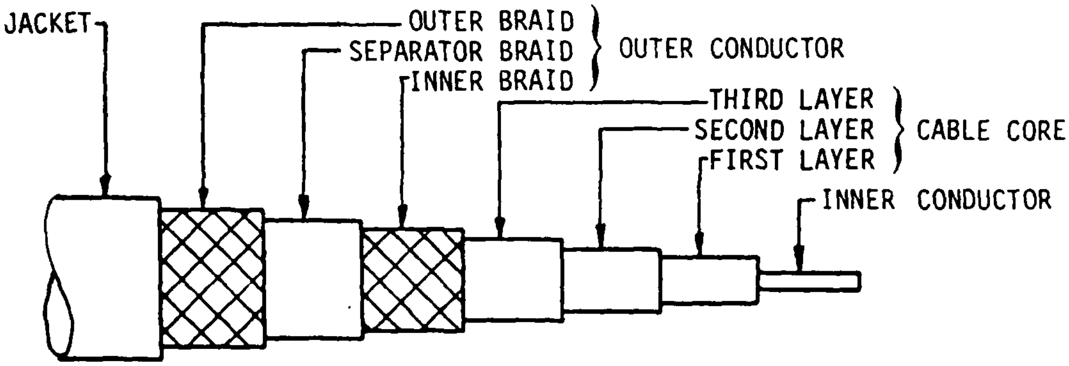


CABLE, RADIO FREQUENCY, COAXIAL, RG-12A/U

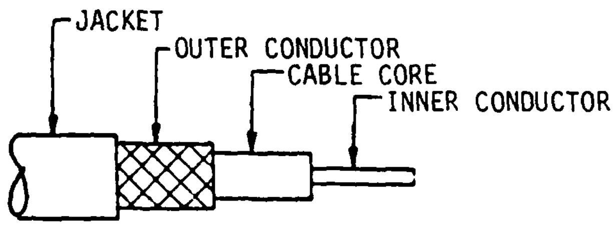


CABLE, RADIO FREQUENCY, COAXIAL, RG-27A/U

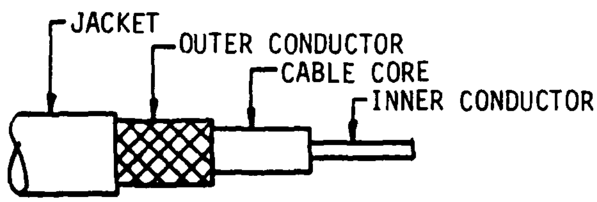
FIGURE 3-6
MIL-C-17 OUTBOARD SONAR SYSTEMS CABLE CONSTRUCTION



CABLE, RADIO FREQUENCY, COAXIAL, RG-28B/U

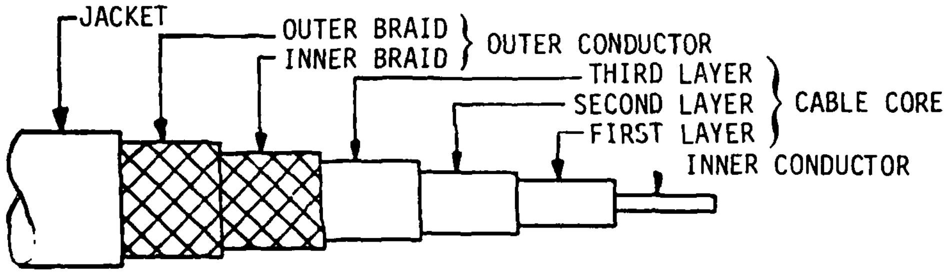


CABLE, RADIO FREQUENCY, COAXIAL, RG-58C/U

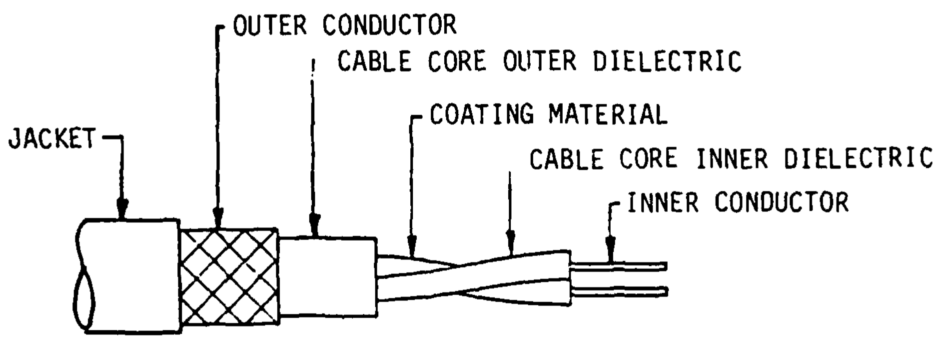


CABLE, RADIO FREQUENCY, COAXIAL, RG-59A/U

FIGURE 3-7
MIL-C-17 OUTBOARD SONAR SYSTEMS CABLE CONSTRUCTION



CABLE, RADIO FREQUENCY, COAXIAL RG-54A/U



CABLE, RADIO FREQUENCY, COAXIAL, DUAL, RG-130/U

FIGURE 3-8

MIL-C-17 OUTBOARD SONAR SYSTEMS CABLE CONSTRUCTION

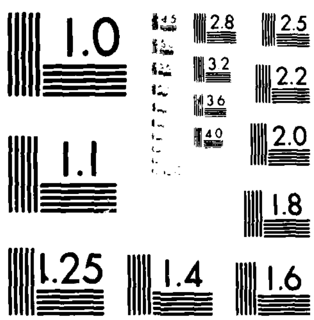
AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

UNCLASSIFIED NRL-MR-4601 NL

2 OF 8

AD

1193



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

TABLE 3-5

MIL-C-17 Outboard Sonar System Coaxial
Cable Construction Details

Cable Type	Conductor Type	Conductor Diameter	Core Diameter	Outer Conductor Diameter	Cable Diameter
RG-8A/U	7/.0285	.087	.275/.295	.340 (Max)	.395/.415
RG-12A/U	7/.0159	.0477	.278/.292	.340 (Max)	.475 (Max)
RG-27/U	19/.0185	.093	.133/.143 .415/.435 .455/.465	.500 (Max)	.580/.610
RG-28B/U	19/.0185	.093	.133/.143 .415/.435 .455/.465	.605 (Max)	.785/.825
RG-58A/U	19/.0071	.0375	.112/.120	.150 (Max)	.191/.199
RG-59/U	Solid	.023	.142/.150	.191 (Max)	.238/.246
RG-64A/U	19/.0117	.059	.080/.100 .238/.258 .278/.298	.368 (Max)	.475 (Max)
RG-130/U (2)	7/.0285	.087	.183/.193	.540 (Max)	.610/.640

3.4 TRIDENT Submarine Cables

Outboard cables used on the TRIDENT submarines are primarily new designs. The cables are listed and detailed in Table 3-7. Those cables specifically used in sonar systems are listed in Table 3-6. The TRIDENT submarine outboard cable types is the first major design change made since World War II. The AN/BQQ-6 sonar system on TRIDENT uses approximately 1000 small hydrophones encapsulated with polyethylene. This has required that a polyethylene jacketed cable be wired and molded to the hydrophone. As a result, cable 1PR-A20E, Reference 3-3, was designed for the application. The conductor is composed of a number of 20 AWG high strength silver coated copper alloy strands. (Phelps-Dodge PD-135). The conductor is insulated with a Tefzel fluoropolymer (ETFE) and covered with a thin jacket of polyethylene. The two conductors are twisted together and jacketed with a black polyethylene co-polymer. Specifically, the material is a Union Carbide Corporation DFDA-0588, Black 9865 type.

Other cables designed for TRIDENT have made use of a Tefzel insulated number 16 AWG tin coated .060 inch diameter conductor (3/7). The proper number of conductors are twisted together and are jacketed with black polyether polyurethane. This material can be a B.F. Goodrich Company, Estane 58300; or Mobay Chemical Company, Texon 985A polyurethane. It should be noted that none of the above noted cables have any internal waterblocking sealants.

TABLE 3-6

TRIDENT Outboard Cables In Use On Sonar Systems

Cable Type	CPG 1000 Specification Sheet
1PR-16	CPG 1000/3
3PR-16	CPG 1000/20
7PR-16	CPG 1000/18
1PR-A20E	Navy Procurement Specification Sheet

TABLE 3-7

TRIDENT Outboard Cables

EBDivision Cable Spec.	Cable Type	No. Of Conductors	Shields/ Type Of Conductors	Conductor Diameter (Inches)	Conductor Insula. Diameter (Inches)	Cable Diameter (Inches)
CPG 1000/3	1PR-16	2	0/ 3(7)	.060	.082	.380/.400
CPG 1000/4	1SPR-16	2	1/ 3(7)	.060	.082	.380/.400
CPG 1000/8	7SPR-16S	14	8/ 3(7)	.060	.082	.920/.950
CPG 1000/14	1TR-16	3	0/ 3(7)	.060	.082	.380/.400
CPG 1000/16	1Q-16	4	0/ 3(7)	.060	.082	.380/.400
CPG 1000/17	7PL-16	7	0/ 3(7)	.060	.082	.530/.550
CPG 1000/18	7PR-16	14	0/ 3(7)	.060	.082	.630/.650
CPG 1000/19	2SPR-16	4	2/ 3(7)	.060	.082	.630/.650
CPG 1000/20	3PR-16	6	0/ 3(7)	.060	.082	.530/.550
NAVSEC* Spec. Sheet	1PR-A20E	2	0/ 7/.0126	.038	.060	.280/.290
MIL-C-915/8	DSS-3	2	1/ 7/.020	.060	.110	.480/.500
MIL-C-915/8	TSS-4	3	1/ 7/.025	.076	.126	.480/.500
MIL-C-915/49	2SWU-19	38	19/ 7/.0152	.050	.096	1.292/1.380
GE 7094511	RG-12A/U (Mod)	1	1 7/.0159	.048	.278/.292	

* Now NAVSEA.

3.5 DSV-3 and DSV-4 Cables

Outboard cables used on the TURTLE (DSV-3) and SEA CLIFF (DSV-4) are listed in Table 3-8. In most cases, standard Navy MIL-C-915 outboard cables have been used. Neoprene jacketed commercial cables are used where no military equivalent is available and a few proprietary cables are used to suit certain outboard component requirements.

TABLE 3-8

DSV-3 And DSV-4 Outboard Cables

Cable Type	Specification
DSS-3	MIL-C-915/8
FSS-2	MIL-C-915/8
TSS-4	MIL-C-915/8
7SS-2	MIL-C-915/8
MWF-7	MIL-C-915/58
MWF-14	MIL-C-915/58
MWF-24	MIL-C-915/58
SHOF-60	MIL-C-915/6
2SWU-3	MIL-C-915/49
2SWF-3 and 4	MIL-C-915/48
10/2SO	Commercial
18/3SO	Commercial
C105	Hydro Products, Inc.
PWC-815	Plastic Wire & Cable Company
CN-4	Rochester Corporation

3.6 DOLPHIN Cables

Outboard cables used in the DOLPHIN (AGSS 555) are listed in Table 3-9. MIL-C-915 outboard cables are used to meet Dolphin design requirements. MIL-C-17 coaxial cables are used in antenna applications.

TABLE 3-9

DOLPHIN Outboard Cables

Cable Type	Specification
DSS-3	MIL-C-915/8
FSS-2	MIL-C-915/8
TSS-4	MIL-C-915/8
FSS-4	MIL-C-915/8
DSWS-4	MIL-C-915/7
MSS-6	(Cancelled)
2SWF-4	MIL-C-915/48
MWF-10	MIL-C-915/48
RG-14A/U	MIL-C-17/9
RG-17A/U	MIL-C-17/10
RG-264A/U	MIL-C-23020/4

3.7 NR-1 Cables

Cables used outboard on the NR-1 Deep Submergence Vehicle are primarily modified designs of MIL-C-915 outboard cables. The basic cable design changes are increased thickness of conductor insulation and cable jacket. The cables are internally water-blocked and have an arctic neoprene jacket. The cable types are listed in Table 3-10.

TABLE 3-10

NR-1 Outboard Cables

Cable Type	Construction	EBDivision Specification
EBDS-MWF-2 (Mod)	2 -.048" dia. conductors	2348
EBDS-MWF-3 (Mod)	3 -.048" dia. conductors	2348
EBDS-MWF-5 (Mod)	5 -.048" dia. conductors	2348
EBDS-MWF-10 (Mod)	10 -.048" dia. conductors	2348
EBDS-MWF-14 (Mod)	14 -.048" dia. conductors	2348
EBDS-2SWU-1 (Mod)	1 - .048" dia. shielded pair	2349
EBDS-2SWU-2 (Mod)	2 - .048" dia. shielded pair	2349
EBDS-2SWU-4 (Mod)	4 - .048" dia. shielded pair	2349
EBDS-THOF-3 (Mod)	3 - .060" dia. conductor	2347
EBDS-THOF-9 (Mod)	3 - .108" dia. conductor	2347
EBDS-THOF-42 (Mod)	3 - .263" dia. conductor	2347
EBDS-6HOF-4 (Mod)	6 - .075" dia. conductor	2347
EBDS-2SWTVA-4	4 - .050" dia. shielded pair	2374
EBDS-2SWCTFMB	1 - .046" dia. shielded pair	2376
RG-17A/U (Mod)	1 - .188" dia. coaxial no outer conductor	2462
EBDS-2SWDOPA-1	1 - .050" dia. shielded pair	2520
EBDS-2SWDOPA-3	3 - .050" dia. shielded pair	2520
EBDS-2SWDOPA-7	7 - .050" dia. shielded pair	2520

3.8 Deep-Submergence Rescue Vehicle (DSRV) Cables

Outboard cables used on the DSRV are fabricated to Lockheed specification number RV-S-0162, Reference 3-4. Approximately 43 different cable designs are used to manufacture an approximate 244 outboard cable harness assemblies necessary for these vehicles. Many of the cables have a combination of individual conductors and shielded twisted pairs. A few include coaxial type cables. The copper conductor sizes range from number 20 AWG to 2/0 AWG. The conductors are insulated with a polypropylene co-polymer, filled with depolymerized rubber (DPR) for watertightness, and jacketed with neoprene.

It is currently planned to replace these cable assemblies with oil filled type cable harness assemblies. The oil filled harnesses are being fabricated per Lockheed Specification RV-S-2172.

The assembly consists of polyether polyurethane tubing per Lockheed Specification RV-S-2175, wire per Lockheed Specification RV-S-0289, and connectors and backshells per Lockheed Specification RV-S-2171.

3.9 DSV-4 (20,000-ft.) Cables

The SEA CLIFF, DSV-4, is currently being modified for 20,000 feet operating depths. Oil filled outboard cable harnesses designs will be used on this vehicle. The cable harness will conform to NAVSEA Drawing DSV-4-304-5155928, Reference 3-5.

3.10 Sonar Systems Manufacturer Outboard Cables

At various times it has become necessary for Sonar System Manufacturers to design and develop special outboard cable designs to suit particular system requirements. These special cable designs are detailed on vendor drawings and are listed in Table 3-11.

TABLE 3-11

Sonar Systems Manufacturer Outboard Cables*

Manufacturer	Specification Drawings	Remarks
EDO	42892	Harness- ** 8 to 1 Cable
EDO	57026	Faired Cable Assembly
EDO	60-372-1	Shielded 10 cond. cable assy.
EDO	58112-1	47 Conductor Cable Assy.
GE	C77C705423	Harness- 8 to 1 cable
GE	77D603108	Harness- 8 to 1 cable
GI	91E-CA-0033	
MASSA	C30829-501	
MASSA	C-30732-2	
RAYTHEON	430679	24 Conductor
SANGAMO	820742	
SANGAMO	829026	
SANGAMO	867484	
SANGAMO	2196	

*See listing of manufacturers and addresses, p. 3-32.

**See paragraph 4-17

3.11 Listing of Manufacturers and Addresses

EDO	-	EDO Corporation Government Products Division 13-10 111th Street College Point, NY 11356
GE	-	General Electric Company Box 4840 Syracuse, NY 13221
GI	-	General Instrument Harris ASW Division 33 SW Port Street Westwood, MA 20290
MASSA	-	Massa Corporation 280 Lincoln Street Hingham, MA 92043
RAYTHEON	-	Raytheon Company Submarine Signal Division West Main Road P.O. Box 360 Portsmouth, RI 02871
SANGAMO	-	Sangamo Western, Inc. SDRD P.O. Box 3041 Sarasota, FL 33578

REFERENCES

3-1 MIL-C-915, "Cable and Cord, Electrical, for Shipboard Use, General Specification for"

3-2 MIL-C-17. "Cables, Radio Frequency, Flexible and Semi-rigid, General Specification for"

3-3 Naval Ship Engineering Center Procurement Specification, "Cable, Electrical, One Twisted Pair AWG-20, for TRIDENT Submarine Outboard Use (not for Inboard Use) - Type 1PR-A20E"

3-4 Lockheed Specification No. RV-S-0162, "Cable, Electrical, (Deep Submergence)"

3-5 NAVSEA Drawing DSV-4-304-5155928, "General Specification for Connectors, Oil Filled for Deep Submergence Vehicle Cabling"

3-6 Naval Weapons Support Center Drawing No. 4551225, "Cable Electrical, Special Purpose, Butyl 600 VAC", Specification Control Drawing.

3-7 GLOWE, D.E., and ARNETT, S.L., "Investigation of the Strength of Shielded and Unshielded Underwater Electrical Cables", NRL Memorandum Report No. 4468, 1981.

(Blank)

SECTION 4

NAVSEA APPROVED CABLE HARNESSES

(Blank)

4.1 Introduction

A pressure-proof cable harness as installed on submarines and surface ships is an electrical cable having connectors wired and molded to one or both ends of the cable. Most sonar system electrical cables used outboard on submarines are in accordance with MIL-C-915, Reference 4-1. Surface ship cable harnesses are special designs which are detailed on sonar system vendor drawings such as Reference 4-2. The rubber connectors wired and molded to these cables are also detailed on these drawings. The pressure-proof connectors used on submarine sonar systems are the MIL-C-24231 type, Reference 4-3; the TRIDENT CPG 1027, type, Reference 4-4 (modified MIL-C-24231); the MIL-C-24217 type, Reference 4-5; the MIL-C-22539 type, Reference 4-6. Molded cable glands are also used on a number of sonar system hydrophones and transducers. These are detailed on the individual component assembly and detail drawings. Reference 4-7 is a typical example of a component cable gland.

The connectors and cable glands are wired and molded to the cables in accordance with Navy approved procedures as noted in the following paragraphs.

4.2 MIL-C-24231 Connector Cable Harness

Most cable harnesses used outboard on submarines make use of MIL-C-24231 connector plugs. These plugs are polyurethane rubber molded to the cables in accordance with the detailed procedures provided in NAVSHIPS 0962-022-2010, Reference 4-8. These procedures were prepared by the Portsmouth Naval Shipyard for NAVSEA and are periodically updated by the shipyard.

4.3 MIL-C-24217 Connector Cable Harnesses

A number of sonar system components make use of MIL-C-24217 connectors. These connectors were initially designed for use in conjunction with neoprene rubber molding procedures. These procedures are detailed on NAVSEA drawing 815-1197381, Reference 4-9. Procedures are provided in NAVSEA drawing 815-1197377, Reference 4-10, for molding to FSS-2 type cables. NAVSEA drawing 815-1197380, Reference 4-11, provide procedures for molding to 1SWF-2 type cables.

4.4 MIL-C-22539 Connector Cable Harnesses

A number of sonar system hydrophones have used the now cancelled (for new design) MIL-C-22539 connectors. These connector plugs were designed for neoprene molding. The procedures for wiring and molding these connector plugs are detailed on NAVSEA drawing 815-1197170, Reference 4-12.

4.5 Surface Ship Connector Cable Harnesses

Surface ship cable harnesses are special designs. The harness assembly is comprised of a large main trunk cable with a molded cable junction having eight smaller cables exiting from the junction and running to the individual transducers. The large cable passes through a cable stuffing tube located in the surface ship hull. The transducer cables have a special neoprene plug wired and molded to the end of each cable. The molded plugs are detailed in vendor drawings such as in Reference 4-2. The wiring and molding procedures, however, are not detailed on these drawings. These are proprietary procedures of the harness manufacturer. The harness drawings specify performance requirements to meet the application.

4.6 TRIDENT Submarine Cable Harnesses

Cables used outboard on TRIDENT submarines are polyethylene jacketed (NAVSEA 1PR-A20E type) and polyurethane rubber jacketed (EBDivision CPG 1000 type). The polyethylene jacketed cables are directly molded to the hull penetrators and the individual hydrophones. The cables are spliced and polyethylene molded together on the ships using procedures provided in Electric Boat Division Document CPG 1096, Reference 4-13. The polyurethane jacketed cables are polyurethane molded and wired to the CPG 1027 (modified MIL-C-24231) MIL-C-24217, and special glass sealed D. G. O'Brien MIL-C-24217 plug connectors in accordance with procedures detailed in EBDivision CPG 1060, Reference 4-14. A small number of MIL-C-24217 connector receptacles are polyethylene molded to the polyethylene jacketed 1PR-A20E cables with proprietary procedures of ITT Cannon, Phoenix, Arizona.

4.7 DOLPHIN Submarine Cable Harnesses

The DOLPHIN outboard cables are the MIL-C-915 type and the plug connectors are the MIL-C-24231 type. The plugs are wired and polyurethane molded in accordance with the NAVSEA 0962-022-2010, Reference 4-8, procedures.

4.8 NR-1 Cable Harnesses

The NR-1 outboard cables are modified MIL-C-915 cables. Neoprene molded and polyurethane prepotted MIL-C-24217 connectors are primarily used on the NR-1. The connectors are wired and molded with procedures provided in NAVSEA NR-1 302-2663185, Reference 4-15. A few MIL-C-24231 plugs are also used and these are polyurethane molded in accordance with Reference 4-8, procedures.

4.9 TURTLE DSV Cable Harnesses

The TURTLE outboard cables are the MIL-C-915 and the commercial SO types. These vehicles are fitted with the MIL-C-24217 pressure-proof connectors. These connectors are currently wired and polyurethane molded in accordance with NAVSEA S9074-AA-MMO-010/DSV-3,4, Reference 4-16, procedures.

4.10 Deep-Submergence Rescue Vehicle (DSRV) Cable Harnesses

The DSRV was initially designed to use special Lockheed neoprene jacketed cables per specification RV-S-0162, Reference 4-17 and MIL-C-24217 connectors. The connectors were wired, epoxy prepotted and neoprene molded to Lockheed RV-S-0104; Reference 4-18, procedures. One DSRV vehicle is currently being modified to replace the neoprene molded and jacketed cables with oil filled cables. Special design MIL-C-24217 connectors are being used with these cables. References 4-19 and 4-20 detail the connectors and oil filled cable harnesses. It should be noted that a small number of modified MIL-C-24217 aluminum bodied connectors are also used on the DSRVs.

4.11 DSV-4 - 20,000 Cable Harnesses

The 20,000 foot operating depth deep submergence vehicle, SEA CLIFF, utilizes oil filled cables and titanium modified MIL-C-24217 type connectors. These harnesses are wired and assembled in accordance with Reference 4-21. The harnesses are detailed in Reference 4-22.

4.12 RAPLOC Wide-Aperture Array Cable Harnesses

The RAPLOC hydrophone cable harnesses make use of the 2SWF-7 type MIL-C-915 cables and modified MIL-C-24231 connectors. The connector plugs are polyurethane molded to the cable with EBDivision CPG 1320, procedures, Reference 4-23.

4.13 Sonar System Component Cable Glands

A number of hydrophones and transducers are designed with cable gland seals. Most designs use neoprene rubber to seal the cables to the gland bodies. The molding methods are usually proprietary procedures developed by the sonar system manufacturers to meet Navy approved performance specifications. The TRIDENT submarine uses two cable gland designs in which the polyurethane jacketed cables are polyurethane molded to the glands with EBDivision 1326, Reference 4-24, procedures.

4.14 AN/BRA-8C Cable Harness

The AN/BRA-8C cable harness is basically a special tow cable which tethers a buoy to the ship and transmit very low frequency radio signals to the ship receivers. The cable penetrates the buoy assembly through a cable gland and is sealed to the gland with a molded rubber boot. In this case, an Ethylene Propylene Diene Monomer (EPDM) rubber compound was formulated to bond to the polypropylene and polyethylene cable constituents as well as the Monel cable gland. These assemblies have been fabricated by the G. W. Dahl Co., Bristol, RI, for the Naval Underwater Systems Center, New London, CT. The cable assembly is detailed on G.W. DAHL Co. Drawing No. 9254-02-0000-500.

4.15 AN/BQR-21 Cable Harness

The AN/BQR-21 outboard cable harness assemblies have been designed and fabricated by the Naval Weapons Support Center, Crane, Indiana. The harness assembly consists of an unshielded butyl jacketed cable with a MIL-C-24231 plug connector and a NUSC/NL secondary seal (see figure 2-6) wired and molded on one end and a special cable gland molded to the other end. The plug and cable gland are sealed to the cable with a molded butyl rubber which is bonded to the cable jacket and the metal shells of the plug and cable gland. The plug assembly is also fitted with a secondary seal gasket assembly as shown on figure 2-6. The cable harness assembly is detailed on Naval Ship Systems Command drawing no.: 80064-4551201.

4.16 AN/BQR-19 Cable Harness

The AN/BQR-19 cable harnesses have been designed by the Raytheon Corporation, Lexington, MA. The harness assembly consists of a 24 conductor neoprene jacketed cable with a 30 contact MIL-C-24231 straight plug connector wired and neoprene molded to one end of the cable and a special 54 contact MIL-C-24231 type plug connector neoprene molded to the other end of the cable. The plugs are designed with neoprene contact inserts and the plug sleeves are potted with epoxy. The 54 contact plug is a right angle type and the plug sleeve and coupling ring are fabricated from type 316 stainless steel. The cable harness is detailed on Raytheon Drawing No. 430679, Reference 4-25 and the cable is detailed on Raytheon specification A364424, part number A364424-1.

4.17 AN/SQS-26 Cable Harness

The AN/SQS-26 cable harness is similar to the surface ship cable harness assembly described in Paragraph 4.5. The harness has a large diameter main trunk cable with a molded cable junction and eight smaller diameter cables eminating from the junction. Rubber connectors are wired and molded to the ends of the eight small cables. The Edo Corporation, College Point, New York, details this harness assembly on Reference 4-26.

4.18 AN/SQS-38 Cable Harness

The AN/SQS-38 cable harness has been designed by the Edo Corporation, College Point, New York. A special design cable has a cable gland molded to one end of the cable and a special 54 contact connector is wired and molded to the other end of the cable. The harness assembly is detailed on Reference 4-27.

4.19 AN/SQS-35 Cable Harness

The AN/SQS-35 cable harness is also designed by the Edo Corporation. The special design cable assembly has a special design connector assembly molded to each end of the cable. The harness assembly is detailed on Reference 4-28.

REFERENCES

4-1 MIL-C-915, "Cable and Cord, Electrical, for Shipboard Use, General Specification for"

4-2 General Electric Co., Drawing 77D603109, "Cable Element, Outline"

4-3 MIL-C-24231 (SHIPS), "Connectors, Plugs, Receptacles, Adapters, Hull Inserts and Hull Insert Plugs, Pressure-Proof, General Specification for"

4-4 Electric Boat Division Specification CPG 1027, "Connectors, Plug and In-Line Receptacle, Molded, Electrical, 3, 4, 7, 9, 14, 24, 30 and 40 Conductor, Pressure-Proof"

4-5 MIL-C-24217 (SHIPS), "Connectors, Electrical, Deep Submergence Submarine"

4-6 MIL-C-22539 (SHIPS), "Connector Sets, Electrical, Hermetically Sealed, Submarine"

4-7 NUSW, Crane, Indiana, Drawing No. 4553363, "Cable Gland", and NUSW Drawing No. 4592757, "Cable Gland Assembly"

4-8 NAVSHIPS 0962-022-2010, "Molding and Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables"

REFERENCES

(Continued)

4-9 NAVSEA Drawing 815-1197381, "Connector, Electrical, Watertight, Submarine, Wiring and Molding Procedures (MIL-C-24217)"

4-10 NAVSEA Drawing 815-1197377, Sheets 2 and 3, "Connector-Watertight- 5 Pin, Wiring and Molding Procedures for 1 SWF-2 Cables"

4-11 NAVSEA Drawing 815-1197380, Sheets 1 and 2, "Plug for FSS-2 Cable-Wiring and Molding Procedure"

4-12 NAVSEA Drawing 815-1197170, "Connectors, Hermetically Sealed, 3, 4, and 5 No. 12 and 8 No. 16 Pins"

4-13 Electric Boat Division CPG 1096, "Procedure for Splicing Type 1PR-A20E Polyethylene Jacketed Cables on TRIDENT Submarines"

4-14 Electric Boat Division CPG 1060, "Procedures for Wiring, Molding, Inspection and Testing Pressure-Proof Electrical Connectors for TRIDENT Submarines"

4-15 NAVSHIPS Drawing NR-1-302-2663185, "Wiring, Molding, Testing, Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators", Naval Ship Engineering Center, Washington, D.C.

REFERENCES

(Continued)

4-16 NAVSEA S9074-AA-MMO-010/DSV-3, 4, "Technical Manual - Fabrication, Installation, Maintenance and Repair, Outboard Cable Harness Assembly Turtle (DSV-3) Sea Cliff (DSV-4)", Prepared by the Mare Island Naval Shipyard, Naval Sea Systems Command, 1/1978.

4-17 Lockheed Missile & Space Company, Specification RV-S-0162, "Cable, Electrical (Deep Submergence)"

4-18 Lockheed Missile & Space Company, Specification RV-S-0104, "Fabrication of Submersible Electrical Cable Assemblies"

4-19 Lockheed Missile & Space Company, Specification RV-S-2171 "Connectors, Pressure Compensated Oil Filled (PCOF), Electrical"

4-20 Lockheed Missile & Space Company, Specification RV-S-2172 "Assembly of PCOF Electrical Cable Harnesses"

4-21 NAVSEA Drawing No. DSV4-320-5157234 "Oil Filled Harness Assembly Procedures for SeaCliff (DSV 4)"

4-22 NAVSEA Drawing No. DSV 4-304-5155928, "General Specification for Connectors, Oil-Filled for Deep Submergence Vehicle Cabling"

REFERENCES

(Continued)

4-23 Electric Boat Division Procedure CPG 1320, "Procedures for Wiring, Molding, Inspection and Testing Pressure-Proof Electrical Connectors for RAPLOC - Wide Aperture Array"

4-24 Electric Boat Division CPG 1326, "Procedures for Molding, Inspection and Testing Transducer Cable Glands for TRIDENT Submarines"

4-25 Raytheon Corporation Drawing No. 430679, "Cable Assembly"

4-26 Edo Corporation Drawing No. 43892, "Stave Cable Assembly"

4-27 Edo Corporation Drawing No. 58112, "Transducer Cable Assembly"

4-28 Edo Corporation Drawing No. 57026, "Electrical Cable Assembly - Special Purpose"

(Blank)

SECTION 5

NAVSEA APPROVED SUBMARINE HULL PENETRATORS

LIST OF FIGURES

LIST OF FIGURES (cont'd.)

LIST OF TABLES

5.1 Introduction

This section describes the pressure-proof electrical hull penetrators in use on submarines, surface ships and deep submergence vehicles of the U.S. Navy. The following hull penetrator types are the preferred components to be used on Navy vehicles for sonar system applications:

- Submarines - MIL-C-24231
  Hull Penetrators
- Surface Ships - MIL-S-24235
  Cable Stuffing Tubes
- Deep Submergence Vehicles -
  Special Hull Penetrators
  Utilizing MIL-C-24217
  Connector Designs

The following paragraphs provide design criteria for hull penetrators, and offer design details for those hull penetrators presently in U.S. Navy service.

5.2 Electrical Hull Penetrator Design

The basic purpose of electrical hull penetrators is to allow the passage of electrical circuits through the pressure hull while preserving the watertight integrity of the hull. Tables 5-1 and 5-2 list the design factors and criteria that must be considered in the development of electrical hull penetrators. Prominent among these is the passage of the largest number of conductors through as small a hole as possible; a primary and secondary conductor water barrier; retention of the penetrator in the pressure hull under depth charge conditions; corrosion resistance; and a design which will not compromise electrical/electronic performance of the system.

A good example of penetrator design is shown on Figure 5-1. Holes placed in a pressure hull require compensation. This is provided by a hull insert welded to the hull. The hull penetrator shown on Figure 5-2 requires a 1-5/16-inch bored hole to allow the passage of thirty to forty conductors - some requiring shields. The bore size in this case is dictated by the spacing required to seal the conductors as they pass through the secondary conductor seal which is a grommet stuffing tube. A 2-5/8 inch diameter penetrator body is required to provide the K-Monel material necessary to withstand the underwater explosion shock forces. Once the hole size required to pass the conductors through the hull is determined, then over 1/2 inch of metal is required to "surround" the hole to provide a pressure-proof and depth charge-proof enclosure.

One of the major considerations in penetrator design is the requirement for a primary and secondary conductor seal. The primary seal is normally located outside the pressure hull and the secondary seal is located inside the hull. Should the primary seal be severed or damaged, the secondary seal provides the desired pressure-proof hull protection. These seals are usually of a crush seal design.

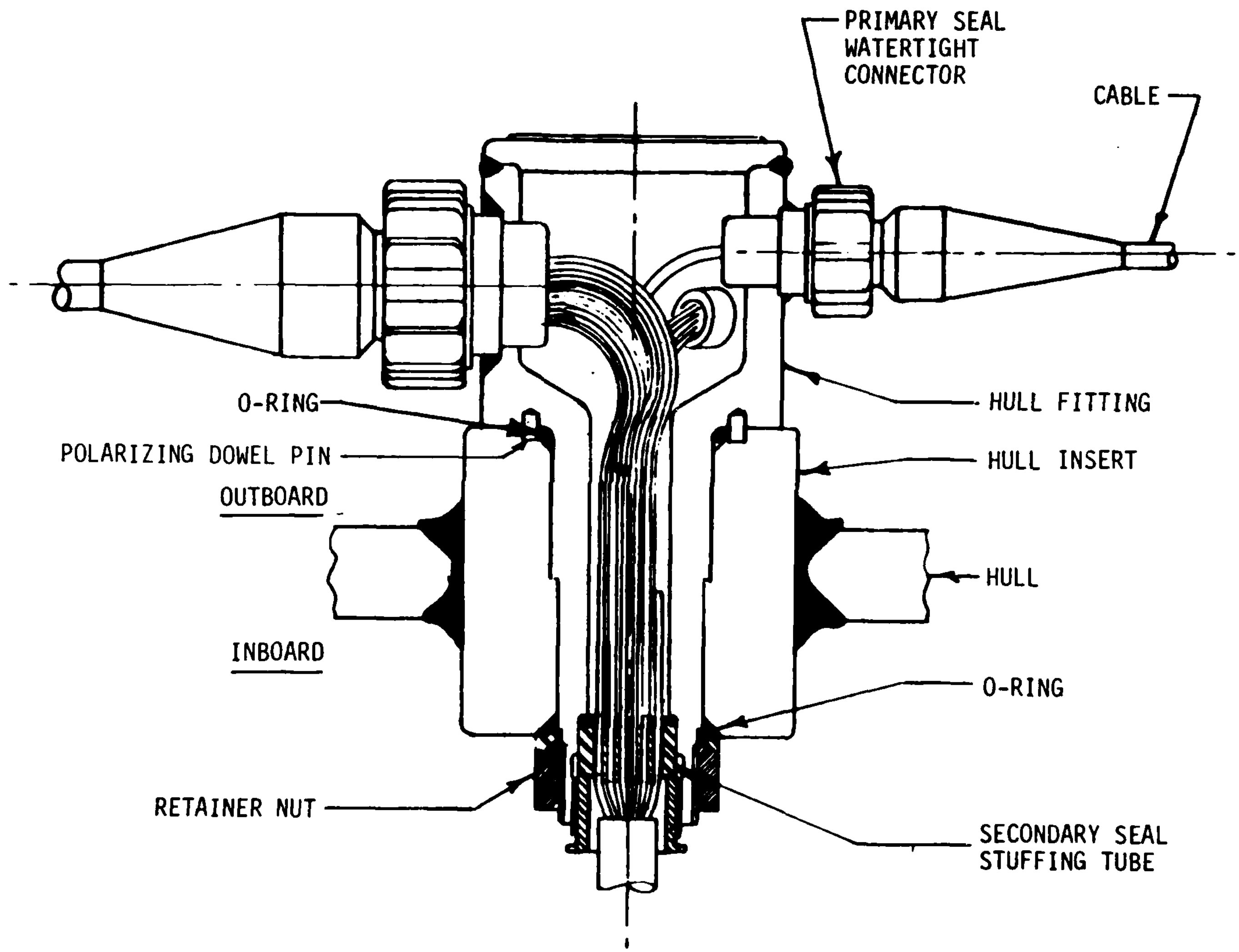


FIGURE 5-1 MIL-C-24231 MULTI-CONNECTOR SUBMARINE HULL PENETRATOR

5.2 (Continued)

Ten shielded twisted pair cables (DSS-3) are accommodated in the largest multi-connector penetrator presently available for tactical submarine applications. Ten individual shielded twisted pair cables pass through the secondary grommet conductor seal. Ten receptacles (which provide the primary conductor seal) are mounted to the turret type outboard junction box which is an integral part of the penetrator body.

A single connector penetrator is the largest size penetrator available to pass 40 conductors through the hull. The maximum number of shielded twisted pair cables that can be sealed in the secondary seal grommet is 12. See Figure 5-2.

Electrical penetrators presently in use have proven to be fully acceptable with respect to corrosion resistance. The K-Monel bodies have withstood the seawater environment for well over two decades. The primary and secondary O-ring seals, housed in a triangular groove, have also been satisfactory in sealing the penetrators to the hull. Retention of the penetrator with an inboard retainer nut is also a proper design choice. It allows quick installation and removal of the penetrator, and the retention device (threads) is not subjected to the seawater environment.

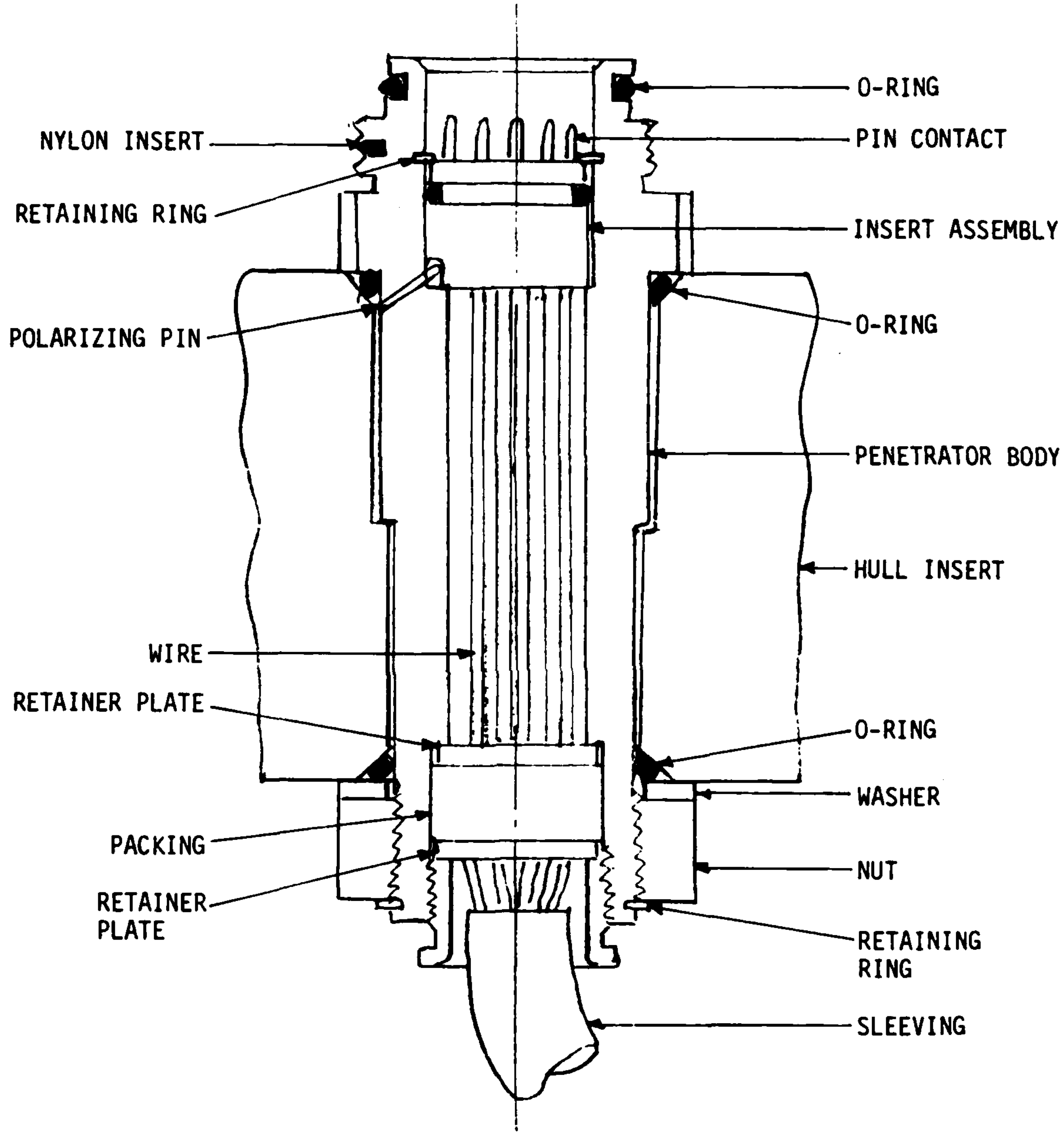


FIGURE 5-2 MIL-C-24231 SINGLE CONNECTOR SUBMARINE HULL PENETRATOR

TABLE 5-1

HULL PENETRATOR DESIGN FACTORS

1. Configuration and Size
2. Cable Entry Configuration and Seal
3. Number of Cables Accommodated Per Penetrator
4. Fastening - Penetrator to Hull
5. Sealing - Penetrator to Hull
6. Hull Insert Type
7. Insulation and Seal - Conductor
8. Flexibility - Design
9. Material Selection
10. Seawater Corrosion Properties of Materials
11. Fabricability
12. Safety
13. Strength - Subsafe
14. Strength - Underwater Explosion
15. Thermal Properties
16. Cost

5.2 (Continued)

Electrical hull penetrator design considerations which serve as criteria in the development of penetrator designs is as follows:

1. There should be two electrical conductor waterdams in each penetrator. It is desirable that these dams be located on the inboard and outboard sides of the penetrator body.

2. There should be one redundant seal as a backup to the primary seal on all outboard openings in a penetrator shell.

3. There should be one redundant seal as a backup to the primary seal between the penetrator and hull insert.

4. Materials and configuration selection should provide resistance to corrosion in a seawater and air environment.

5. The penetrator to hull fastening method should be designed for easy removal of the penetrator.

6. The penetrator should be provided with polarizing pins which properly orient the penetrator in the hull insert and prevents penetrator rotation on its seals during the fastening process.

7. The inboard side of the penetrator should be provided with an electrical disconnect. A connector at this boundary provides a test point for checking outboard circuitry.

8. Adequate wire or cable strain relief must be provided at the inboard penetrator plug, when used.

5.2 (Continued)

9. The penetrator should be designed such that it can be hydrostatically pressure tested prior to installation. This should be accomplished with all seal conditions identical to those at installation in the hull insert. The hydrostatic pressure test should be equivalent to 1-1/2 times the operating depth of the submarine.

10. The configuration of the penetrator must be such that it can be wired without the need for blind assembly procedures dictated by an insufficient cavity or poor internal contour. This consideration has an important bearing on electrical reliability of the penetrator.

11. All wire terminations within the penetrator should be sealed and supported. This combined moisture barrier and conductor strain relief can be accomplished with the use of potting compounds.

12. Protection and support of outboard and inboard cables at the point of departure from the penetrator is required for system reliability.

13. The primary penetrator conductor seal design must be such that damage to one outboard cable will not result in flooding any of the other cables being sealed in that penetrator.

14. The penetrator must be designed to withstand underwater explosion test requirements. The penetrator must be mechanically and electrically functional following these tests.

15. The penetrator configuration should provide for packaging a high conductor density in a minimum envelope, and have a low projection from the hull.

5.2 (Continued)

16. The penetrator must be free of electrical (electromagnetic and electrostatic) and electroacoustic interference for all conductors passing through the penetrator.

5.3 MIL-C-24231 Submarine Hull Penetrators

The MIL-C-24231 electrical hull penetrators were designed and tested at the Portsmouth Naval Shipyard, Kittery, Maine for NAVSEA in the late 1950's. The hull penetrators were designed for military submarine use to replace the cable stuffing tube type penetrators which had been in use in previous years. Two basic types of connectorized hull penetrators are detailed in MIL-C-24231, Reference 5-1; a single connector type and a multi connector type. The MIL-C-24231 specification also details connector plugs which are used in conjunction with the hull penetrators. Since 1960, all new military submarine construction has made use of the MIL-C-24231 hull penetrator designs with the exception of TRIDENT submarines which have employed a modified MIL-C-24231 design. This modification is covered later in this section.

The multi connector hull penetrator, Figure 5-1, is comprised of a K-Monel penetrator body to which Monel connector receptacle bodies are welded around the cylindrical turret portion of the penetrator on the outboard end. Pin contacts are insulated and sealed in a molded epoxy cylindrical receptacle insert located in the receptacle body. The insert is O-ring sealed to the receptacle body, polarized and retained with a special retaining ring. Wires soldered to the pin contacts exit the epoxy insert and run down the center of the penetrator body through a retainer plate and rubber packing assembly located at the inboard end of the penetrator body. The receptacle insert provides the primary conductor seal and the packing assembly provides the secondary seal. The hull penetrator is sealed to the hull insert with O-ring gaskets located in triangular grooves on the inboard and outboard sides of the hull insert. The hull insert is fabricated from HY-80 steel; the same material as the hull plate. Monel cladding is provided at the O-ring grooves to provide a corrosion resistant seal surface.

5.3 (Continued)

Polarizing pins are located in the hull insert, Figure 5-3, to polarize the penetrator to the hull and prevent penetrator rotation when fastening the assembly to the hull with the inboard K-Monel nut. The inboard wire packing is pressurized with a nickel aluminum bronze gland nut located in the inboard side of the penetrator body.

The single connector hull penetrator, Figure 5-2, is also fabricated from K-Monel. The penetrator design is similar to the multi-connector type with the exception that only one connector is located outboard. This eliminates the need for a cylindrical turret type penetrator body and results in a more easily fabricated assembly. As many as forty number 16 AWG conductors are accommodated in this design. This is also true of the multi connector type as the limiting item is the space available in the inboard packing to provide the wire seal.

The penetrator hull insert, Figure 5-3, is a cylindrical HY-80 steel body detailed in MIL-C-24231. The insert is fully welded to the pressure hull and its function is to provide compensation for the hole placed in the hull to house the penetrator.

5.4 Submarine Sonar Sphere Penetrators

An array of 1241 AN/BQQ-5 (and 1245 for the AN/BQS-6, 6A, 6B, 11, 12, 13) sonar system transducers are located in the forward end of attack class submarines. These transducers radiate outboard from a pressure-proof sonar sphere connected to the main pressure hull with an access trunk. Sonar system components are located within the sphere. A sonar sphere penetrator, Figure 5-4, is located in the sphere hull at the rear end of each transducer. The penetrator also serves as a mounting surface for the transducer.

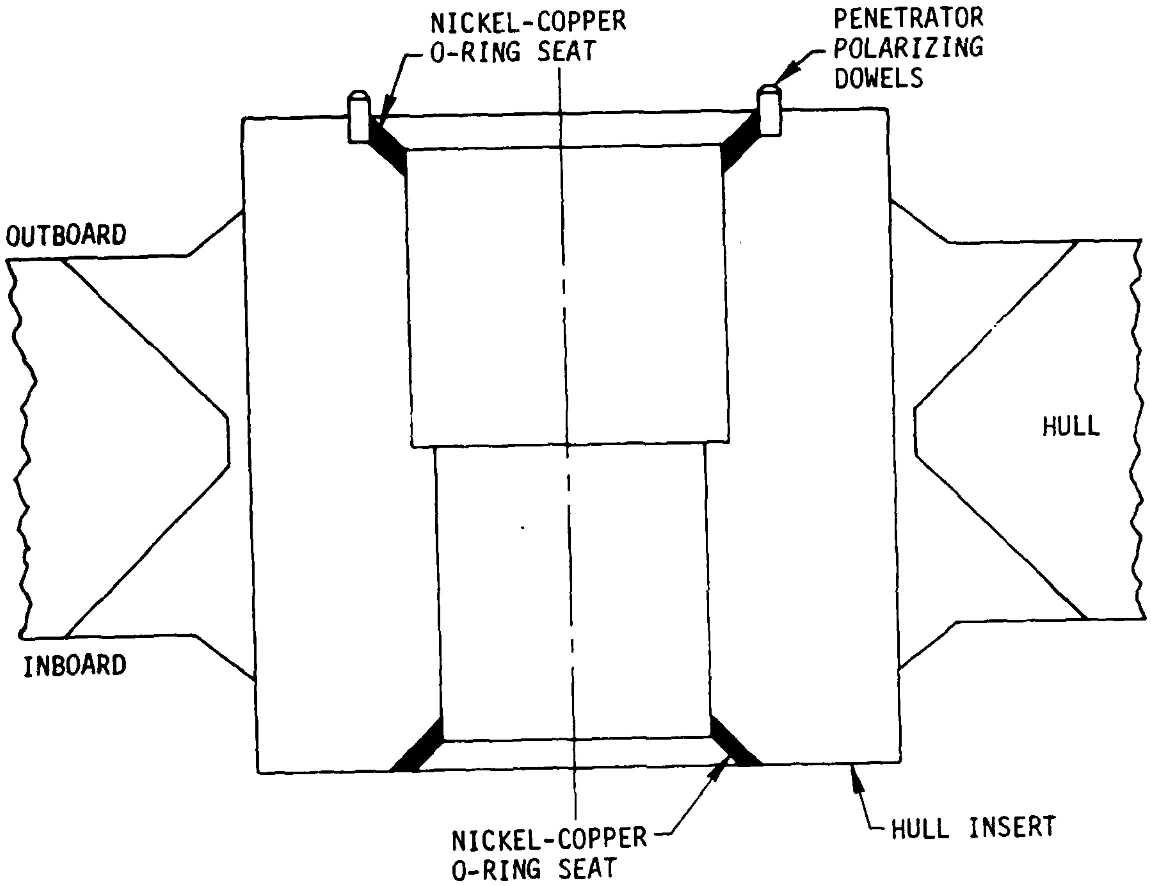


FIGURE 5-3 MIL-C-24231 PENETRATOR HULL INSERT

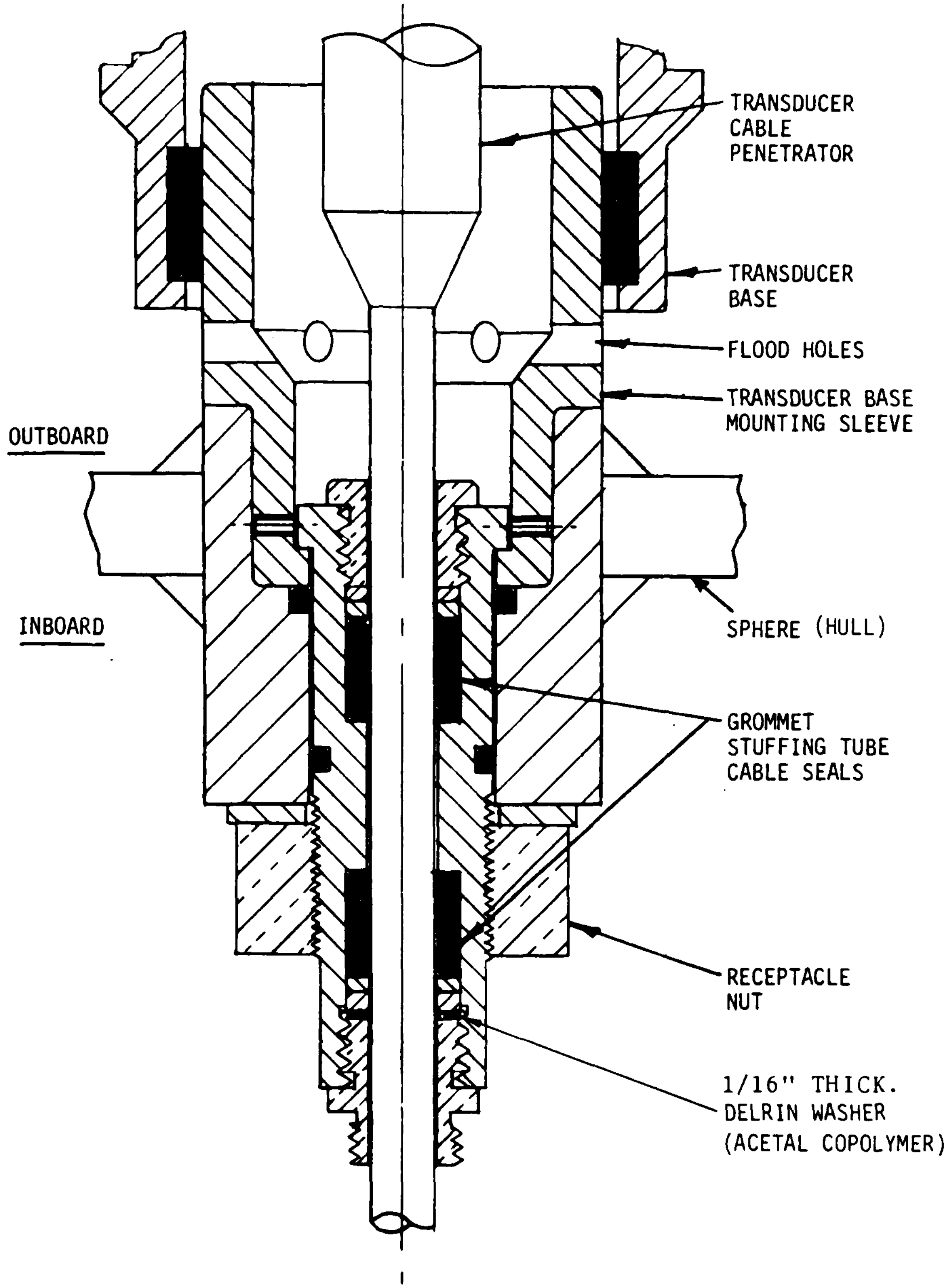


FIGURE 5-4 SUBMARINE SONAR SPHERE PENETRATOR

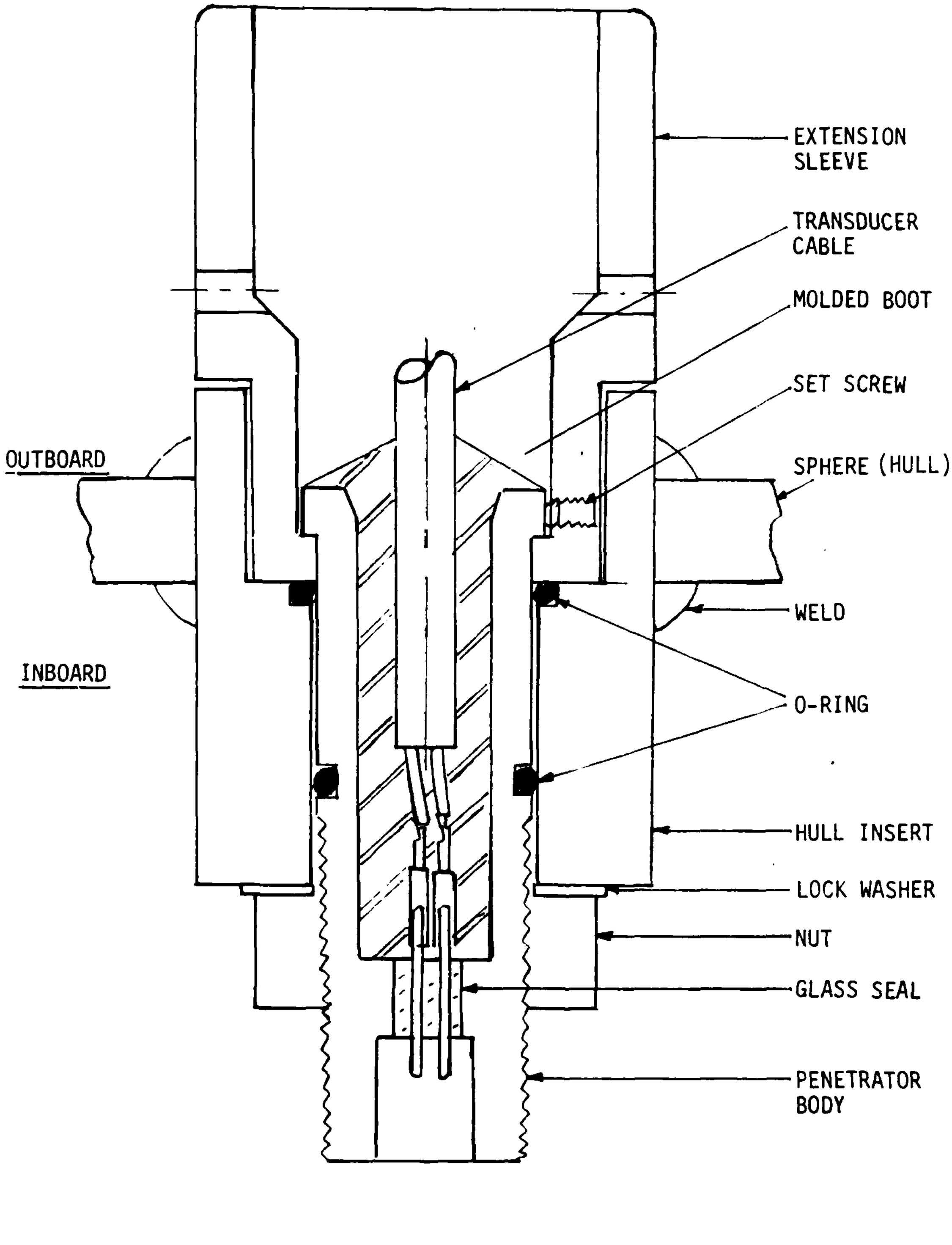


FIGURE 5-5 CONNECTORIZED GLASS SEALED SONAR SPHERE PENETRATOR

5.4 (Continued)

The sphere penetrator is detailed in the Reference 5-2 NAVSEA drawing. The transducer cable is a DSS-3 type sealed to the transducer base with a molded rubber cable gland design. The cable runs directly into a double ended Monel stuffing tube fitting. The inboard cable stuffing tube design includes the use of a Delrin washer to provide additional grommet pressurization to prevent inward cable movement during pressure cycling. The neoprene rubber stuffing tube packings are pressurized with aluminum bronze gland nuts.

A lockwasher is placed between the gland nut and type 304 stainless steel gland ring to keep the packings pressurized. The stuffing tube fitting is sealed to the Monel hull insert, which is welded to the sphere, with two O-ring gaskets. A set screw is used to fasten the tube body to the extension fitting. The extension fitting serves as a mounting fixture for the transducer base. A rubber "doughnut" provides sound and shock isolation of the transducer from the hull penetrator. An inboard lockwasher and hex nut are used to fasten the penetrator to the hull insert.

A design modification is presently being made to the sonar sphere penetrator design and is depicted in Figure 5-5. In this design, the double ended cable stuffing tube has been replaced with a hermetic glass sealed header assembly which seals and insulates two pin contacts which forms a part of the inboard connector receptacle. The transducer cable is sealed to the penetrator body with a molded rubber boot which is bonded to the cable jacket and the penetrator body. The inboard cable is connected to the penetrator with an all molded rubber plug. The plug has a rubber shoulder which is pressurized to the end of the penetrator body with a coupling ring to provide the desired moisture seal. The plug is polarized to the penetrator body with the use of a flat section molded into the front portion of the plug body. The modified penetrator designs are detailed in the Reference 5-3 and 5-4 drawings.

5.5 TRIDENT Submarine Hull Penetrators

The 1044 AN/BQQ-6 spherical and line array hydrophones on TRIDENT submarines are totally encapsulated in polyethylene. Their small size has required that the cable eminating from the hydrophone be directly molded to the assembly. Of necessity the cable jacket material must also be polyethylene. The large number of hydrophones required in this system has necessitated the design of a hull penetrator as depicted in Figure 5-6, (Reference 5-5). A connectorized hull penetrator design was not feasible in this application due to the limited hull space available in the area where the penetrators could be located in the pressure hull. As a result, the penetrator development program provided for accommodating eighteen (18) hydrophone cables in each penetrator. The polyethylene jacketed cables are sealed to the penetrator body with a molded polyethylene boot which is bonded to the cable and the K-Monel penetrator body. The body is castellated in the bond area to provide additional bonding surface. This penetrator design is basically an adaption and enlargement of a British Navy design which normally accommodates eight cables. A primary conductor seal is provided on the outboard side of the penetrator by molding crimp conductor splices in an insulator bushing which is in turn O-ring sealed to the body cover. A secondary conductor seal is provided with the use of a glass sealed 36 pin contact header assembly located on the inboard side of the penetrator. The hull penetrator body configuration is similar to the MIL-C-24231 single connector penetrator to allow installation in a standard MIL-C-24231 hull insert. The penetrator is fitted with a rubber protective collar assembly on the outboard side to protect the cables as they exit the penetrator. An inboard cable plug assembly provides the necessary interface with the inboard penetrator receptacle. The penetrator is polarized, sealed, and fastened to the hull insert in accordance with the MIL-C-24231 penetrator designs.

5.5 (Continued)

Other sonar system penetrators on TRIDENT are the multiple (Figure 5-7) and single (Figure 5-8) connector designs fabricated per Reference 5-6. These penetrators are similar in design to the MIL-C-24231 types with the exception that the inboard end of the penetrators are connectorized. The standard rubber packing used to seal the MIL-C-24231 penetrator conductors has been replaced with a glass sealed pin contact header assembly. Reference 5-7 provides additional details of the penetrators installed on TRIDENT submarines.

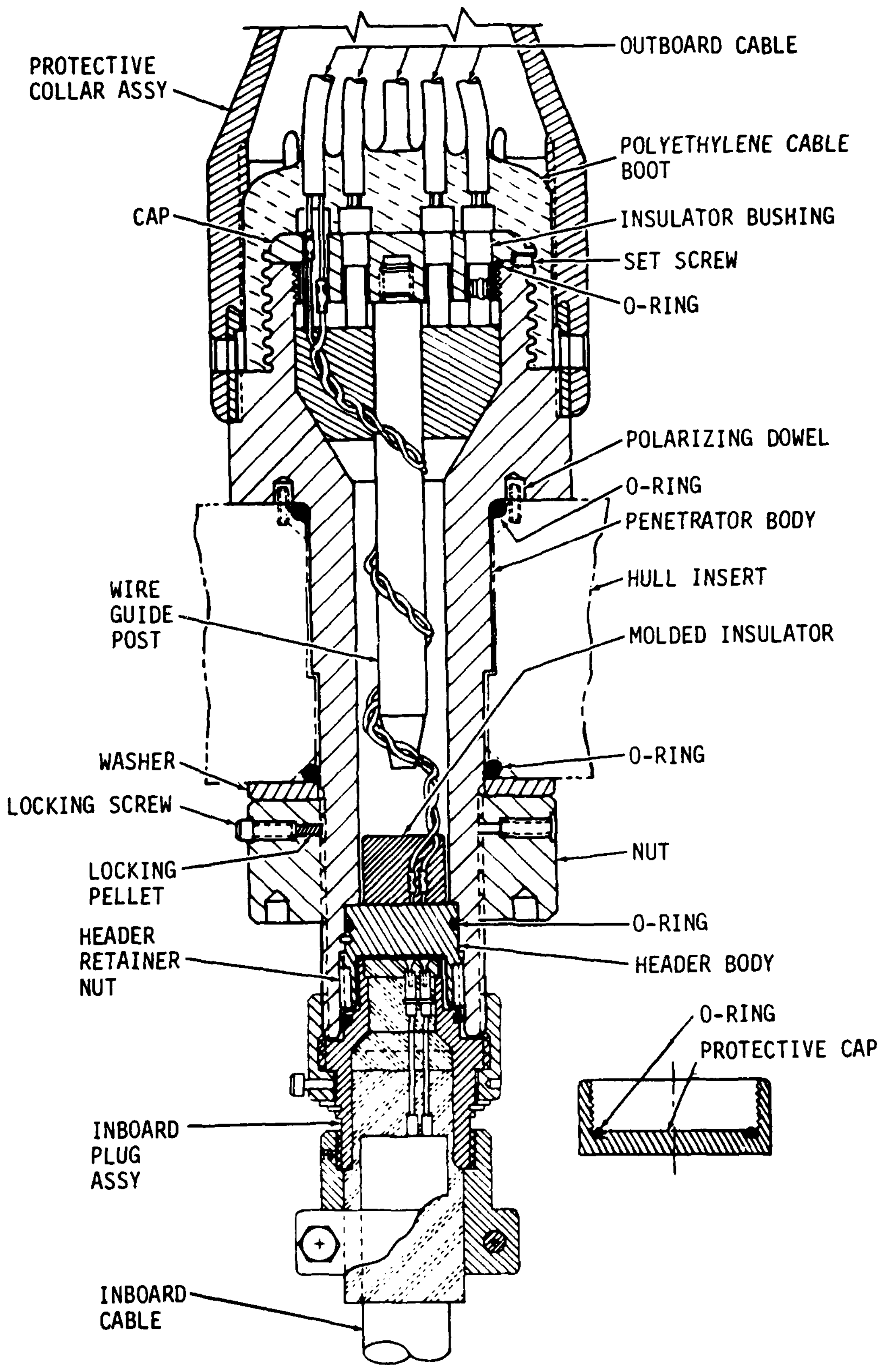


FIGURE 5-6 TRIDENT SPHERICAL AND LINE ARRAY HYDROPHONE HULL PENETRATOR

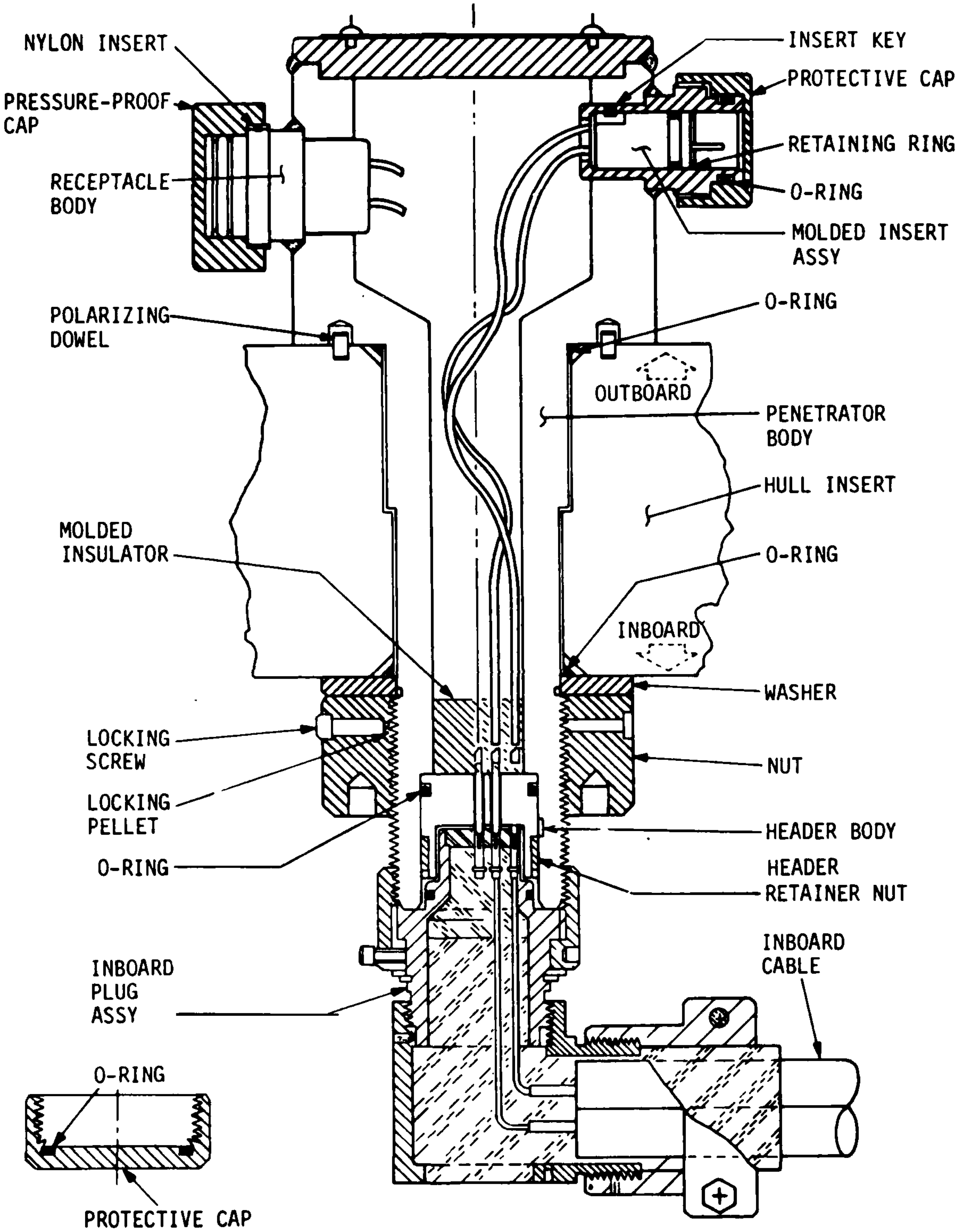


FIGURE 5-7 TRIDENT MULTIPLE CONNECTOR HULL PENETRATOR

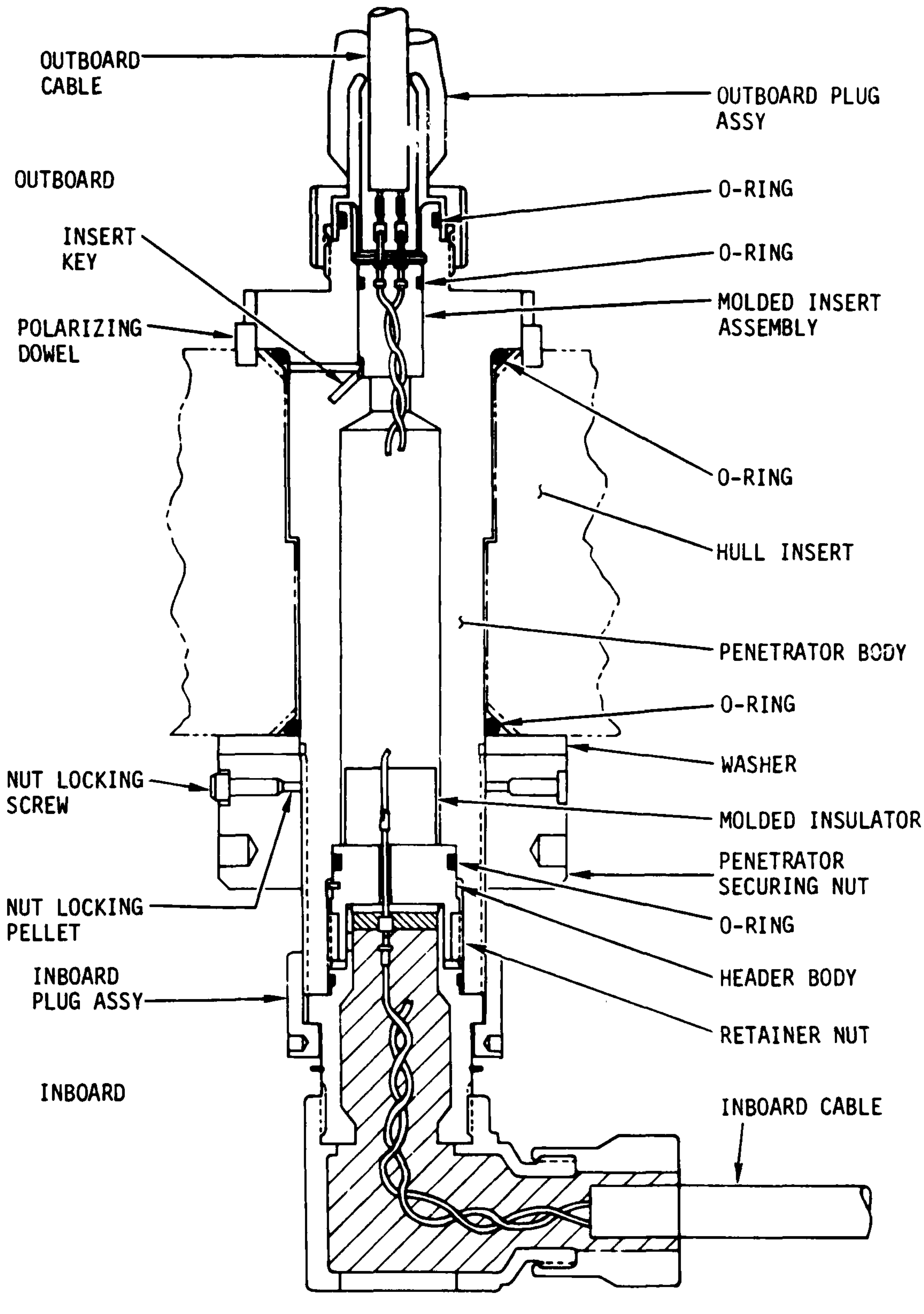


FIGURE 5-8 TRIDENT SINGLE CONNECTOR HULL PENETRATOR

5.6 Surface Ship Cable Stuffing Tube Penetrator

Sonar system cables penetrating the hull of surface ships are preferably sealed in cable stuffing tubes. The approved Navy stuffing tubes are detailed in MIL-S-24235 (SHIPS), Reference 5-8. Figure 5-9 depicts a typical cable stuffing tube design. The tube body is welded to the hull and is usually the same steel material as the hull to facilitate welding. The double ended stuffing tube is fitted with bevel washers, rubber grommets, lockwashers and a brass gland nut to pressurize the grommet. The lockwasher serves to maintain continuing pressurization of the grommet.

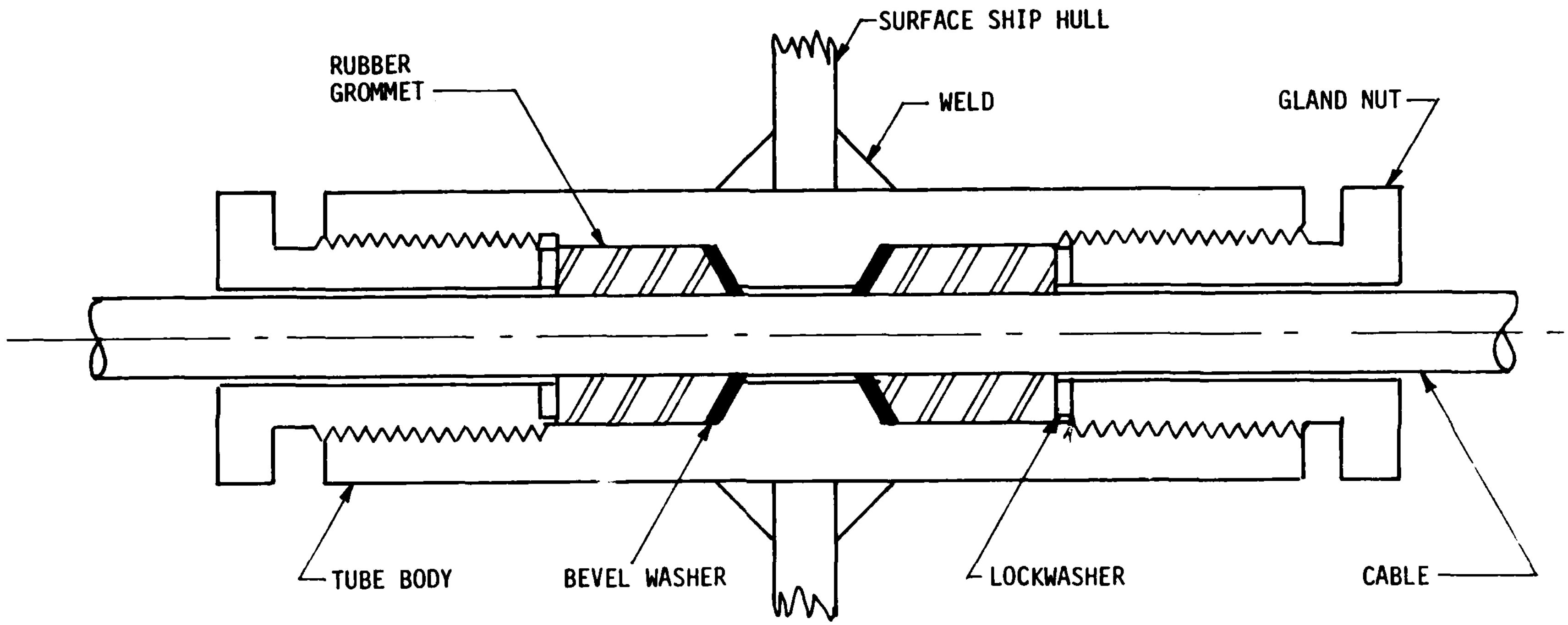


FIGURE 5-9 SURFACE SHIP CABLE STUFFING TUBE PENETRATOR

5.7 DOLPHIN Submarine Hull Penetrator

The single and multiple sonar system penetrators for the DOLPHIN submarine are similar in configuration to the MIL-C-24231 penetrators as seen in Figures 5-10 and 5-11. The exceptions to the MIL-C-24231 designs include the addition of an outboard locking ring used to fasten the penetrator to the hull insert. This ring compliments the inboard nuts which also retains the penetrator in the hull. MIL-C-24231 outboard plugs are used to plug into the penetrator receptacles. The penetrator receptacles, however, are fabricated with glass sealed pin contacts in lieu of the standard MIL-C-24231 epoxy insert assembly. The penetrator secondary conductor sealed is also a glass sealed pin contact header assembly. This replaces the standard rubber packing conductor seal. A plug assembly is used to connect the inboard cable to the penetrator. The multiple hull penetrator accommodates as many as 24 three contact connectors. Penetrator details are provided in the Reference 5-9 and 5-10 drawings.

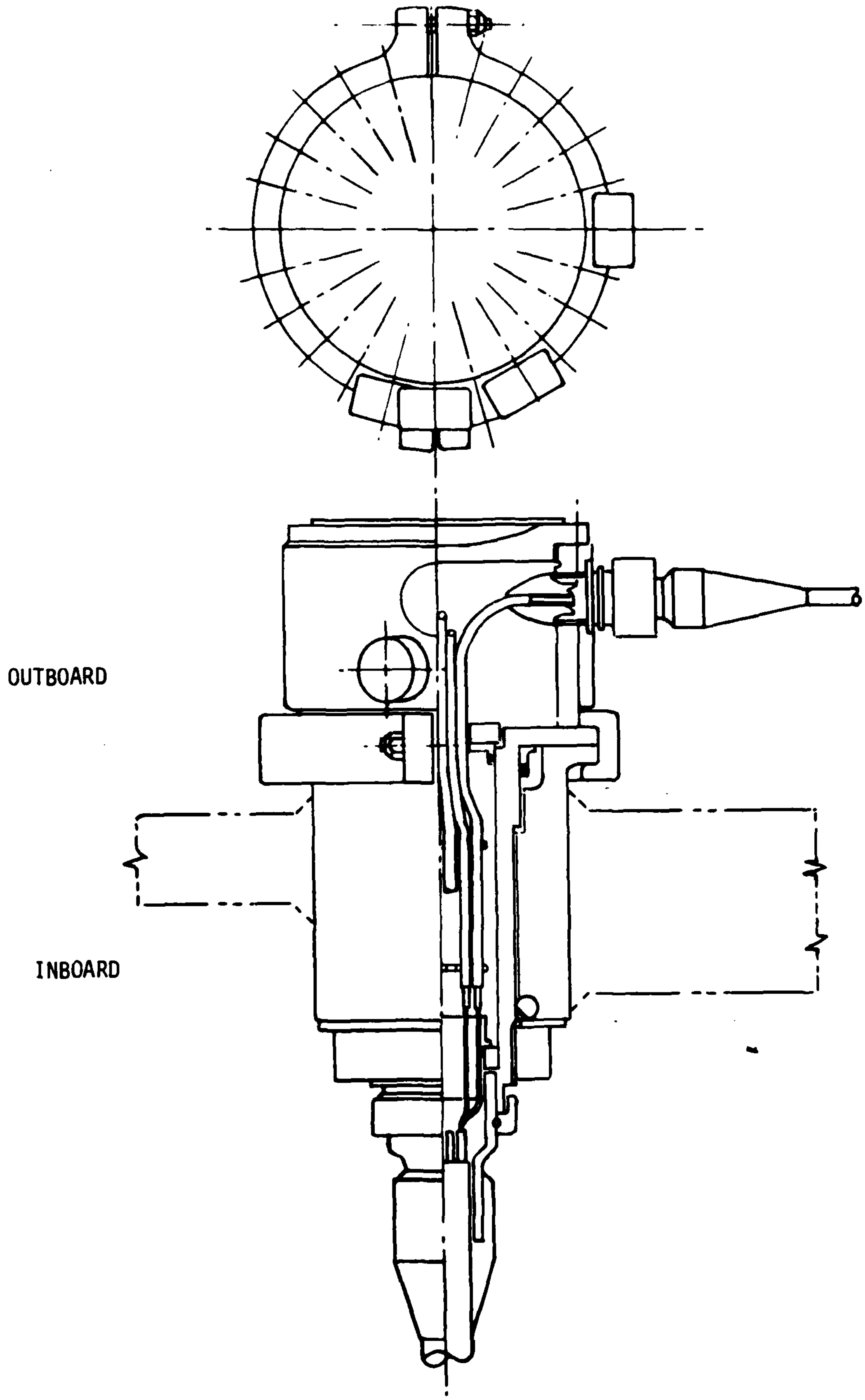


FIGURE 5-10 DOLPHIN SUBMARINE MULTI-CONNECTOR HULL PENETRATOR

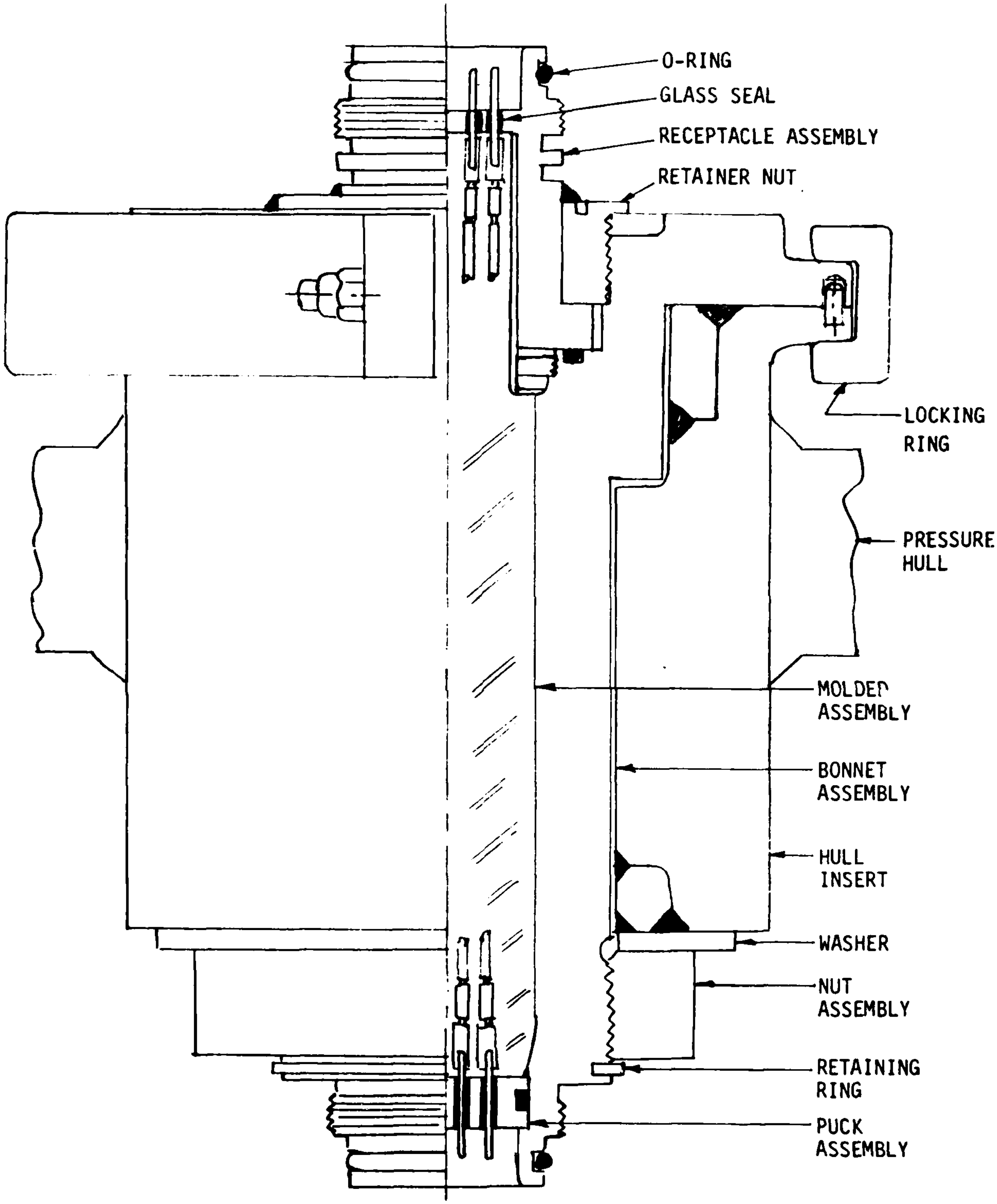


FIGURE 5-11 DOLPHIN SUBMARINE SINGLE CONNECTOR HULL PENETRATOR

5.8 NR-1 Hull Penetrator

The NR-1 multi- connector hull penetrators are also similar in configuration to the MIL-C-24231 penetrators. The penetrator body material, however, is type 316L stainless steel. The use of KAPTON insulated conductors in wiring the penetrator allows 72 number 16 AWG conductors to be sealed in the secondary conductor seal packing. The wrapped conductor insulation is approximately .006 inches thick. As many as 14 MIL-C-24217 glass sealed receptacles can be welded to the ouboard turret side of the penetrator. The penetrator is housed in a MIL-C-24231 type hull insert and is O-ring sealed and fastened to the insert in the same manner as the MIL-C-24231 penetrators. It should be noted that this hull penetrator is not designed for underwater explosion applications such as are required for military submarines.

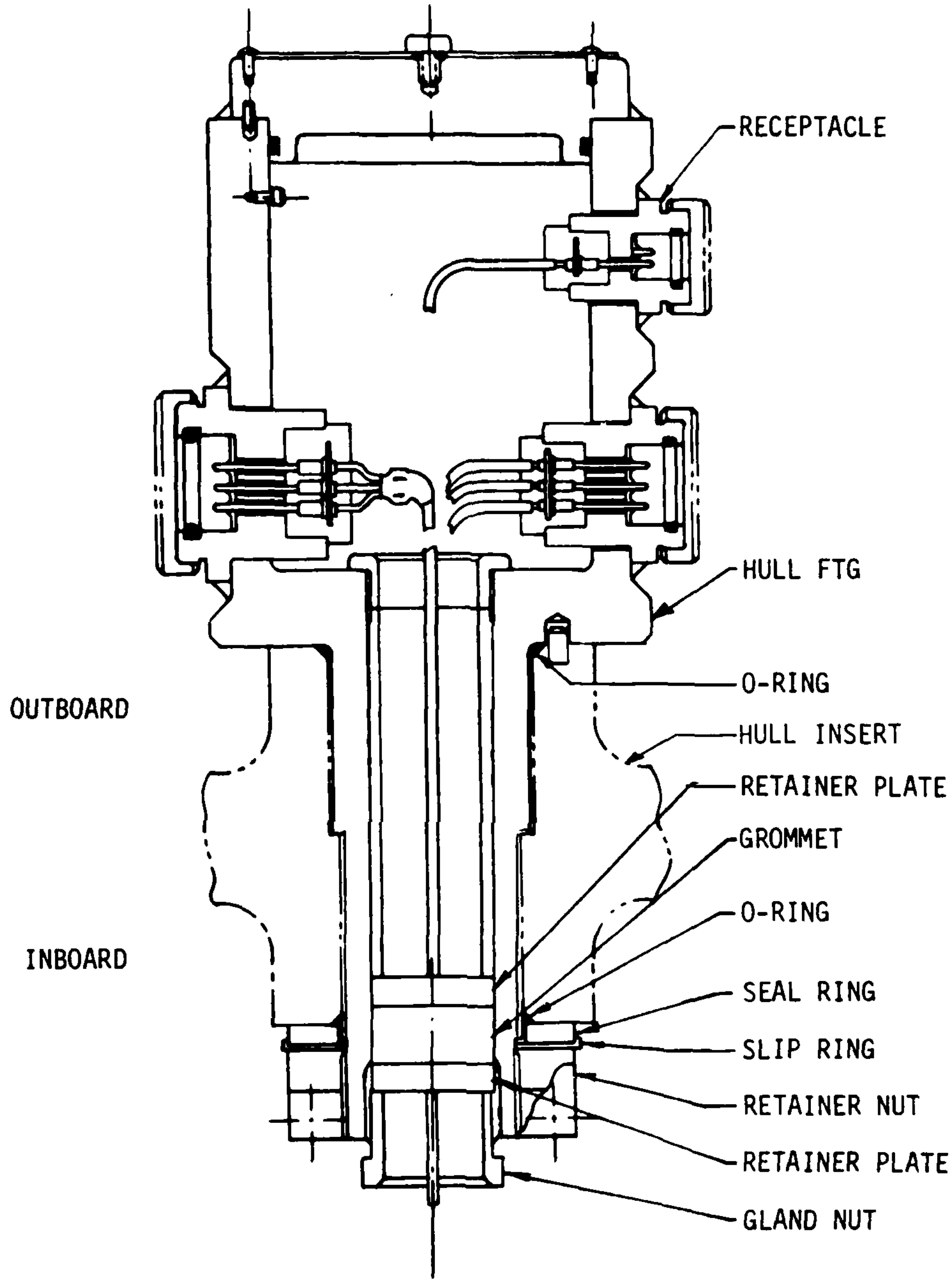


FIGURE 5-12 NR-1 MULTI-CONNECTOR HULL PENETRATOR

5.9 Deep-Submergence Rescue Vehicle (DSRV) Hull Penetrator

The DSRV hull penetrators are a special single connector type designed specifically for that vehicle. Class 316 or 316L stainless steel is used to fabricate the penetrator and plug bodies. The coupling rings are fabricated from aluminum bronze. The penetrator body is multi O-ring sealed to the pressure hull and fastened to the hull with retainer and locking nuts. The contacts within the penetrator are glass sealed in two headers thus providing a primary and secondary seal. Double ended socket contacts are located (and insulated) between the headers. Special O-ring sealed connector plugs are located on the inboard and outboard side of the penetrator body to provide the electrical interface. Molded rubber boots seal the inboard and outboard cables to the plug bodies. Figure 5-13 shows the penetrator design. The assembly is detailed in Reference 5-13.

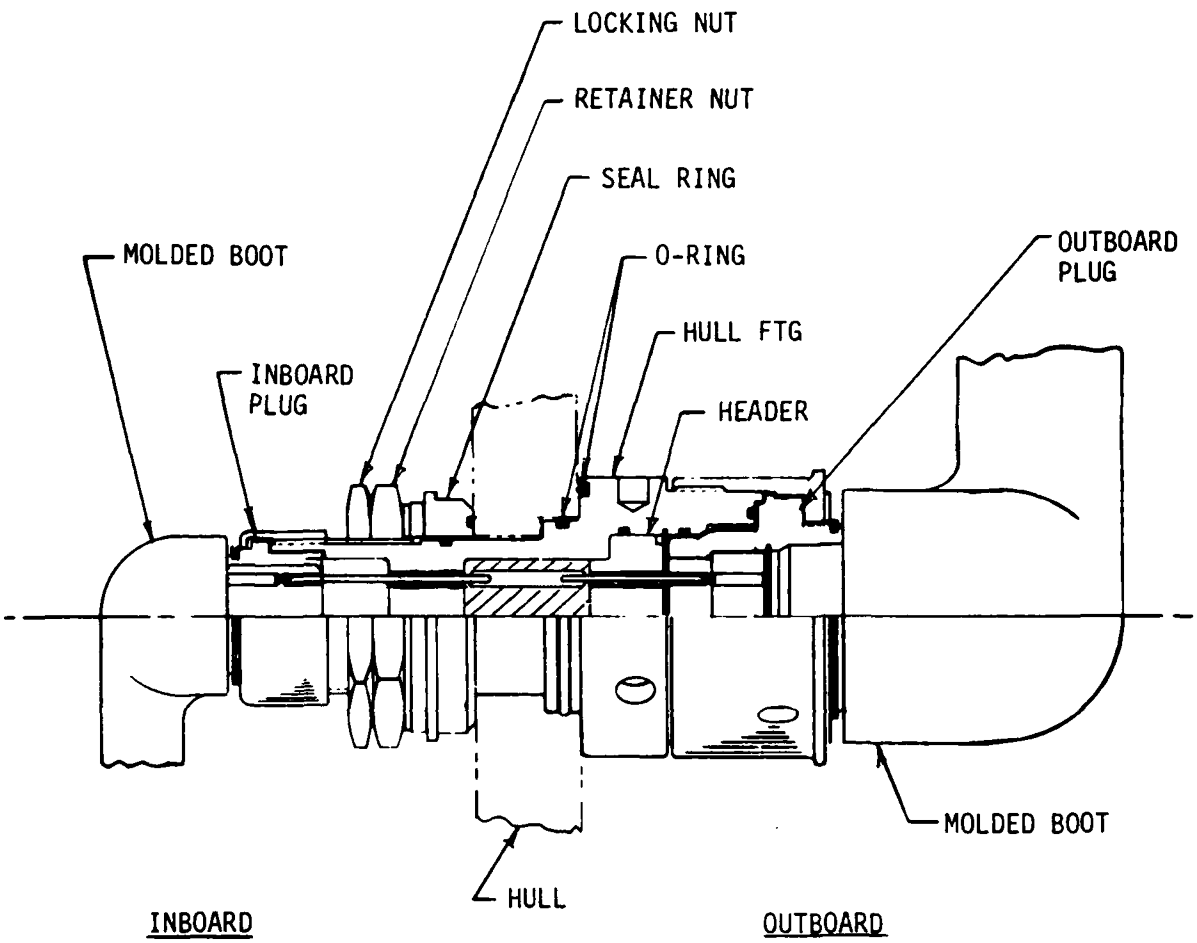


FIGURE 5-13 DSRV HULL PENETRATOR

5.10 TURTLE Hull Penetrator

The TURTLE (DSV-3) electrical hull penetrator is depicted in Figure 5-14 and is detailed in Reference 5-14. The penetrator is a single connector type fabricated from Type 17-4 PH stainless steel. The body is sealed to the hull insert with an O-ring gasket and a tapered metal body-to-insert seal. An inboard retainer nut of aluminum bronze is used to fasten the penetrator to the hull. A flanged type MIL-C-24217 connector with 24 glass-sealed pin contacts is O-ring sealed and bolted to the outboard side of the penetrator. A secondary glass-sealed pin contact header is located inside the body and electrically connected to the receptacle with double-ended socket contacts, which are insulated with silicone rubber. The penetrator internals are also filled with silicone rubber. The number 16 AWG penetrator conductors pass through a Type 304 stainless-steel retainer plate held in place with an aluminum bronze gland nut on the inboard side.

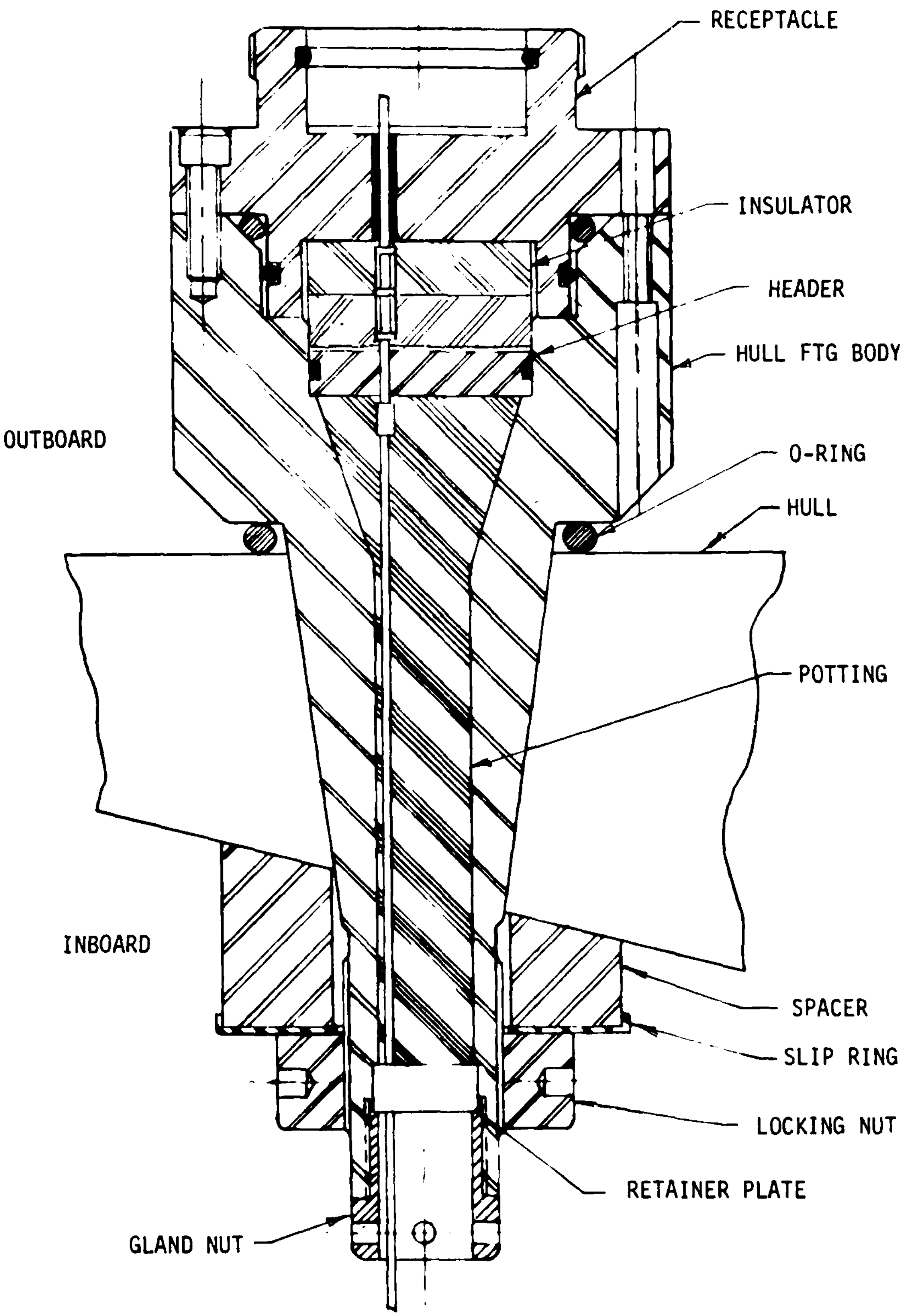


FIGURE 5-14 TURTLE HULL PENETRATOR

5.11 SEA CLIFF Hull Penetrator

The DSV (20,000 foot operating depth) presently in the design phase at the Mare Island Naval Shipyard will utilize a hull penetrator design as shown in Figure 5-15. The penetrator is being designed in accordance with the Navsea specification noted in Reference 5-15 and tentatively fabricated to the details provided in Reference 5-16. The penetrator is basically a single connector design having a tapered titanium body for a metal-to-metal fit at depth in the hull insert. The body is also sealed to the insert with two O-rings. The penetrator is designed to interface with an outboard oil filled plug assembly. The plug body and coupling ring are fabricated from titanium. The plug is O-ring sealed to the penetrator body. A valve is provided in the plug design to allow oil flow between the plug and penetrator interfaces as the plug is mated to the penetrator. The penetrator conductor seals consist of a primary and secondary glass sealed pin contact headers (stainless steel) which are interconnected with insulated socket contacts. The penetrator internals are potted and the body is retained with a retainer and located inboard. The penetrator accommodates 24 number 16 size molybdenum contacts; or 18 number 16 size contacts with one number 0 contact.

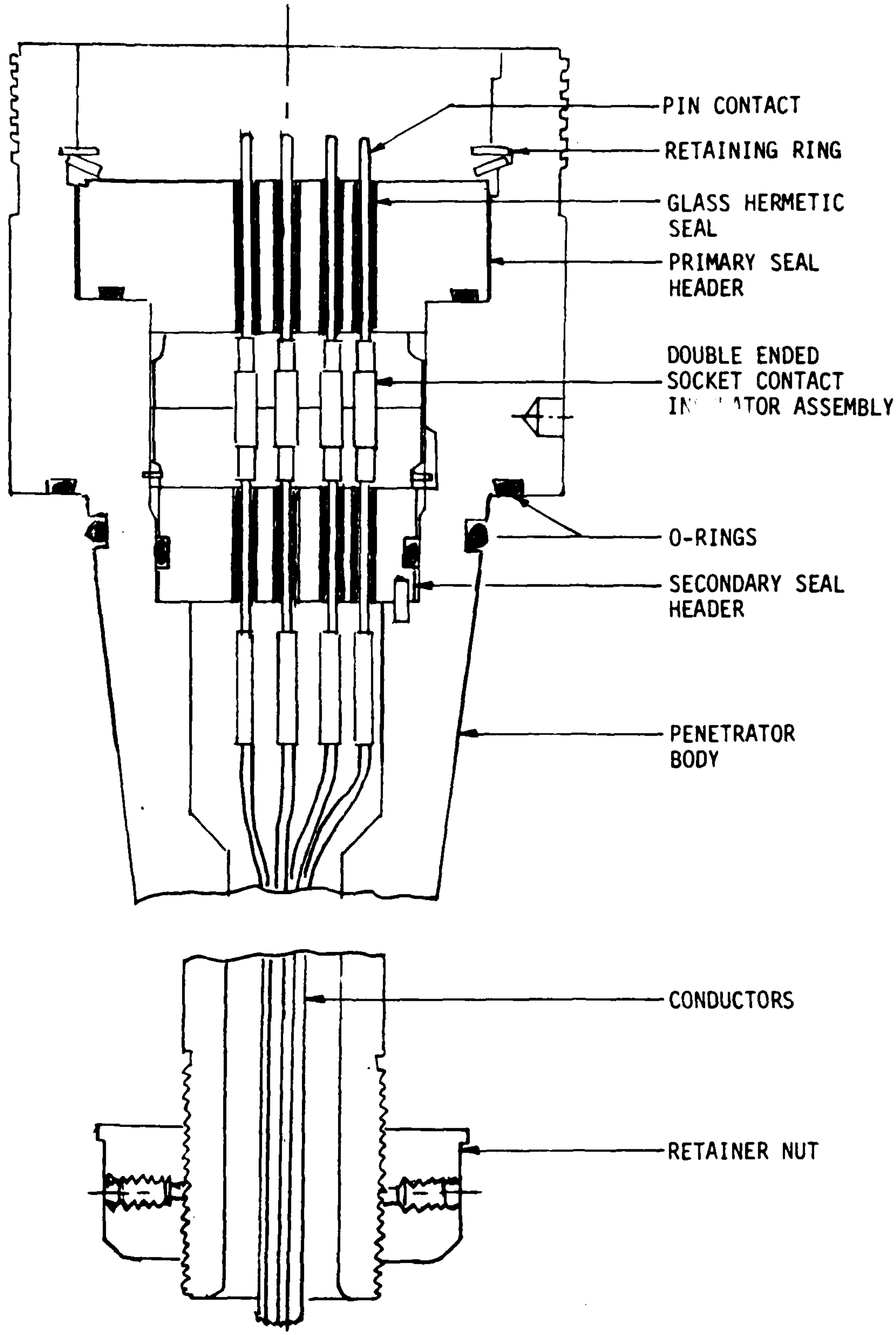


FIGURE 5-15 SEA CLIFF HULL PENETRATOR

5.12 RAPLOC Wide Aperture Array Hull Penetrator

The Naval Underwater Systems Center designed wide aperture hydrophone array will utilize a 120 or 240 conductor penetrator design as shown in Figure 5-16 and detailed in References 5-17 and 5-18. The designs are configured similar to the MIL-C-24231 multi connector hull penetrators.

The 120 conductor penetrator houses eight 15 contact receptacles on the outboard side of the penetrator. Standard 7 contact MIL-C-24231 receptacles have been modified to house 15 number 16 size contacts. One inch in height has been added to the turret portion of the penetrator to allow welding the eight receptacles in two tiers. The receptacles are wired with number 20 AWG high strength wires insulated with KAPTON approximately .006 inches thick. The small conductor diameter allows sealing 120 conductors in rubber packing seal located at the inboard side of the penetrators.

The 240 conductor penetrator houses eight standard 30 contact MIL-C-24231 outboard receptacles. The penetrator is larger in diameter than the standard MIL-C-24231 multi connector penetrator but is designed to fit into the standard MIL-C-24231/25-003 hull insert. All other aspects of the penetrator design are similar to the 120 conductor RAPLOC penetrators.

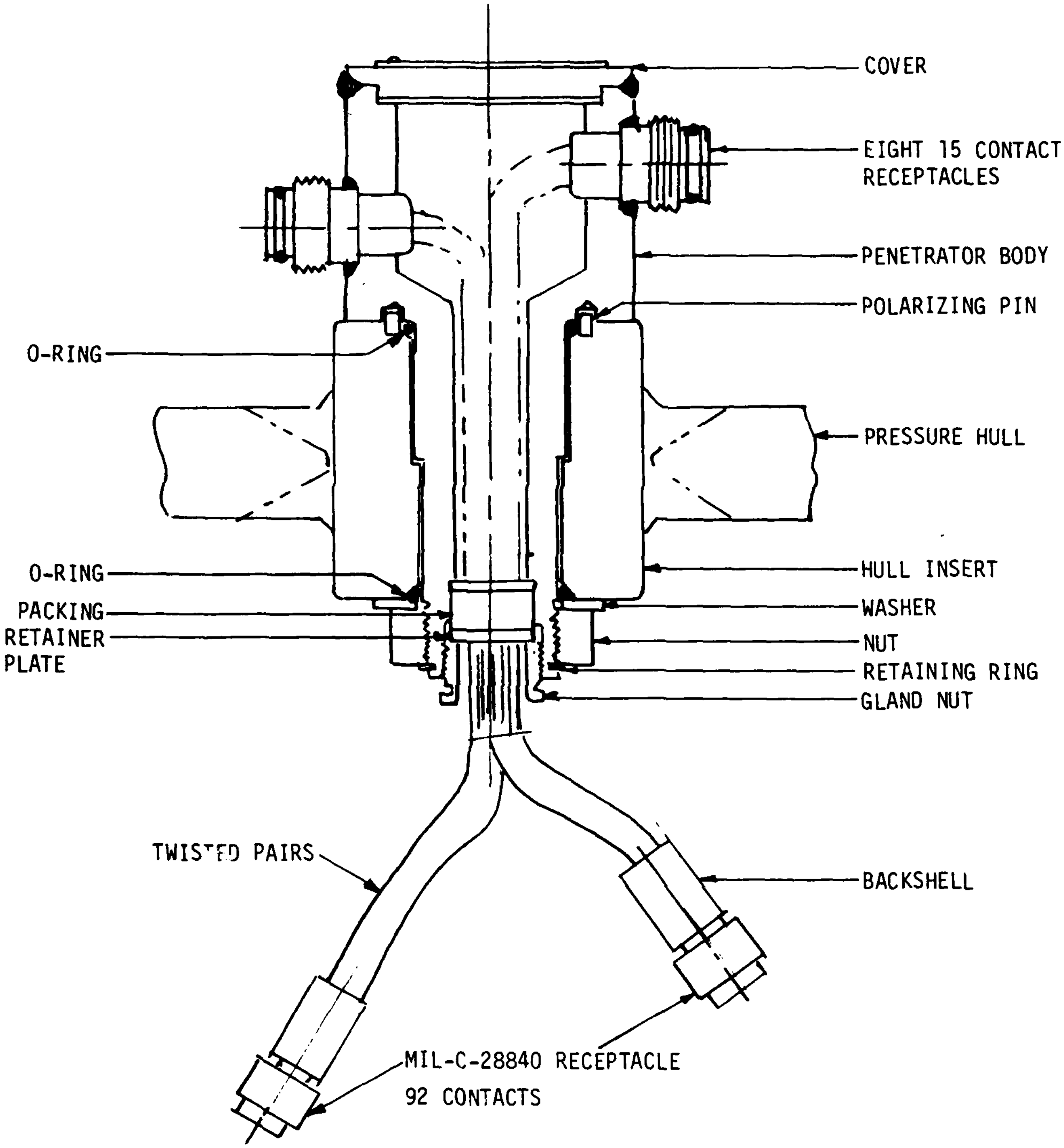


FIGURE 5-16 RAPLOC WIDE APERTURE ARRAY HULL PENETRATORS

5.13 Deep Ocean Technology (DOT) Program 20,000-Ft. Operating-Depth Hull Penetrator

Under the Navy's DOT Program, hull penetrators were designed at Electric Boat Division for 20,000 foot operating depth vehicles. Figures 5-17 and 5-18 show titanium bodied hull penetrators which accommodate 85 number 20 or 48 number 16 size contacts. The bodies are double O-ring sealed to the hull insert and retained with a nut located inboard. In one design, the molybdenum pin contacts are glass sealed in primary and secondary header asemblies located on the inboard and outboard sides of the body. The contacts are inter-connected with a socket contact insulator assembly. The penetrator design depicted in Figure 5-18 has the contacts within the penetrator glass sealed in a long section of the penetrator body. The contact is effectively sealed and insulated for a length in excess of 3 inches. The Bendix Connector Division, Sidney, NY (References 5-19 and 5-20) have patented a method for hermetically glass sealing long contacts. The penetrator is connected on the inboard end with a plug assembly. The outboard side of the penetrator can accommodate a cable plug assembly or a multi receptacle titanium junction box as shown in Figure 5-19.

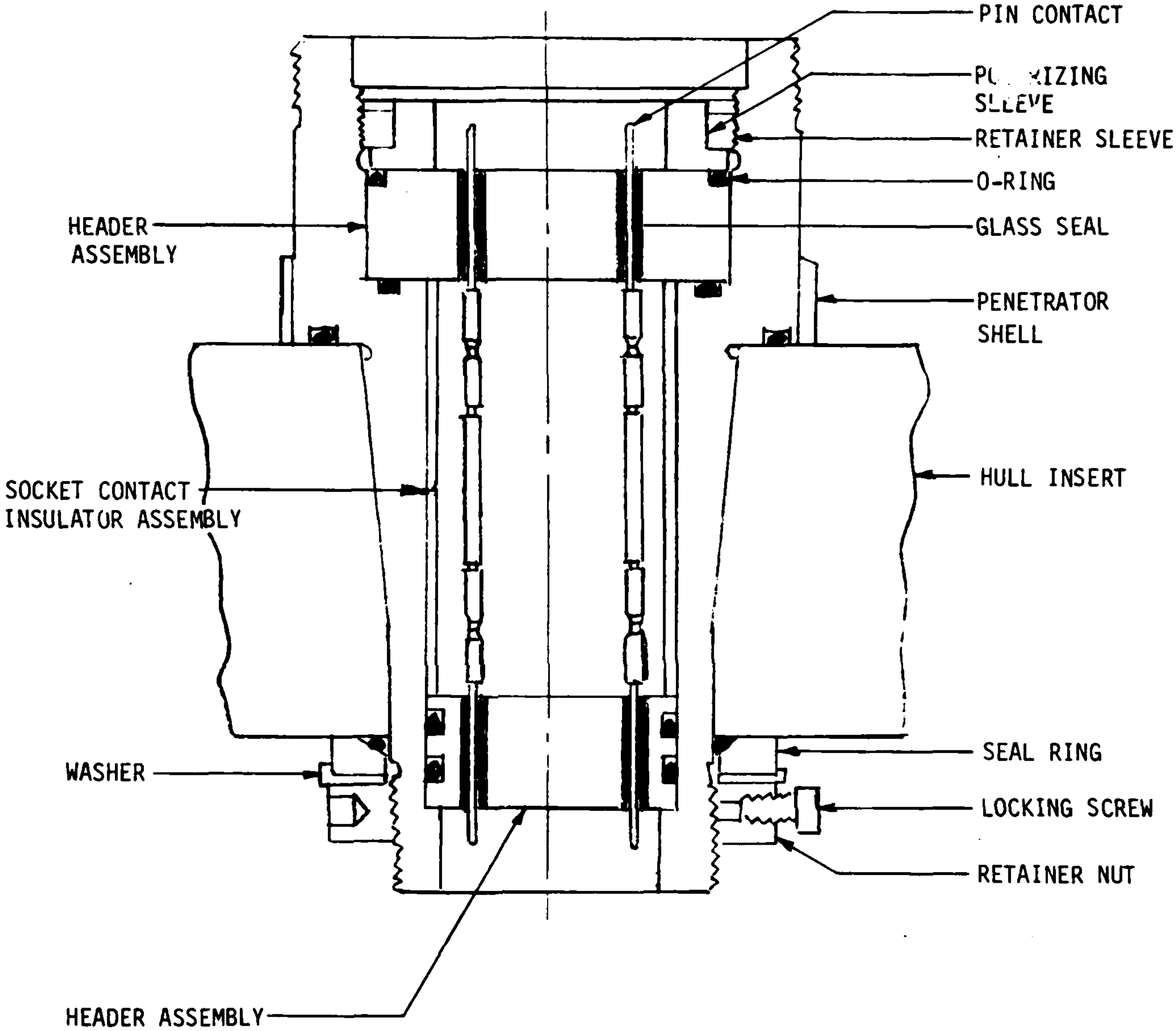


FIGURE 5-17 DOT PROGRAM 20,000 FOOT HULL PENETRATOR

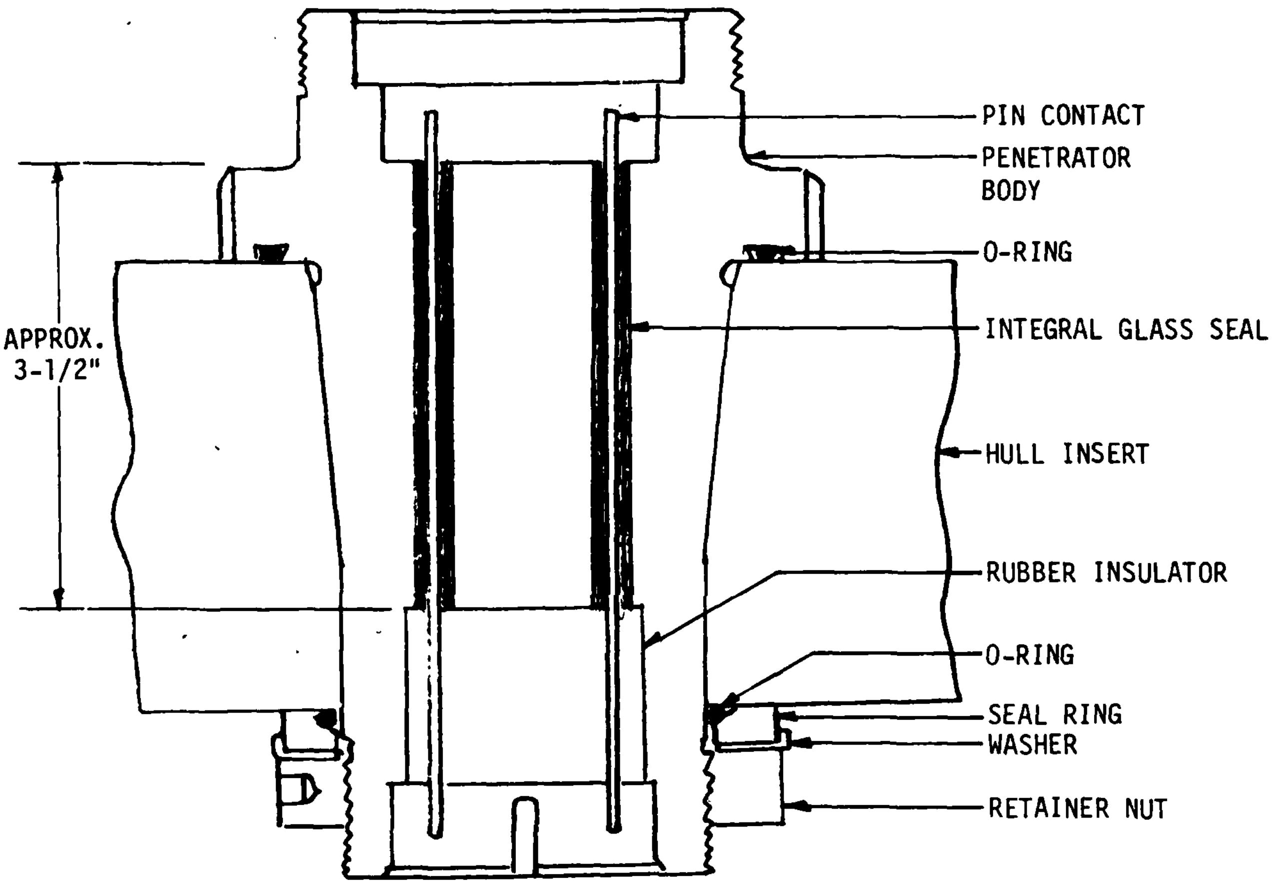


FIGURE 5-18 DOT PROGRAM 20,000 FOOT INTEGRAL GLASS SEAL CONTACT HULL PENETRATOR

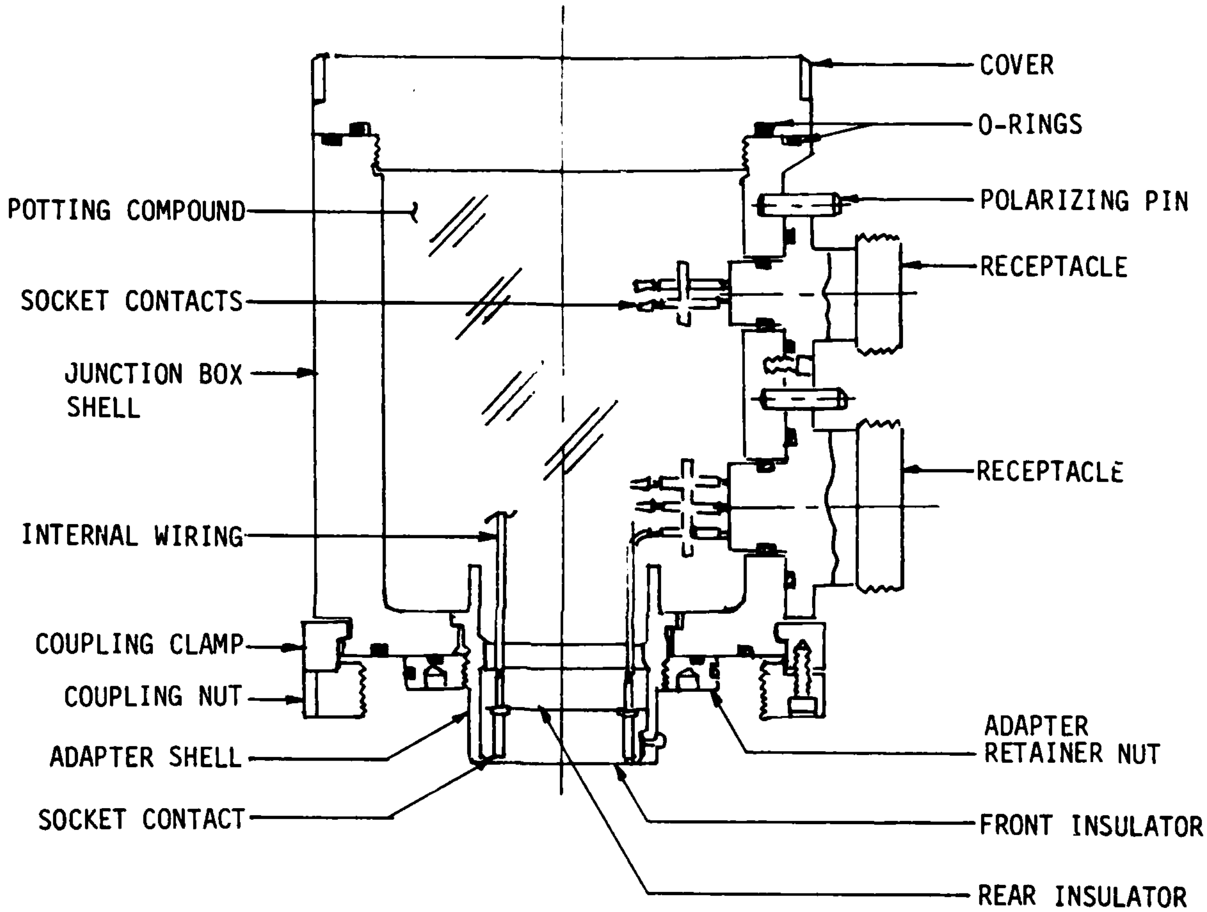


FIGURE 5-19 DOT PROGRAM 20,000-FOOT HULL PENETRATOR JUNCTION BOX

5.14 Multi-Cable Stuffing-Tube Hull Penetrator

A multi cable stuffing tube hull penetrator as shown in Figure 5-20 was used in submarine design following World War II. The penetrator is basically a cylindrical housing fully welded to the submarine pressure hull. The penetrator body material is the same as the hull material to facilitate welding. As many as eight cable stuffing tube assemblies are brazed to the outboard side of the penetrator body to provide the primary seal to the watertight cables such as DSS-3. A secondary cable seal is provided on the inboard side of the penetrator with a rubber packing, retainer plate and gland nut assembly. This penetrator design was superseded by the connectorized types depicted in MIL-C-24231.

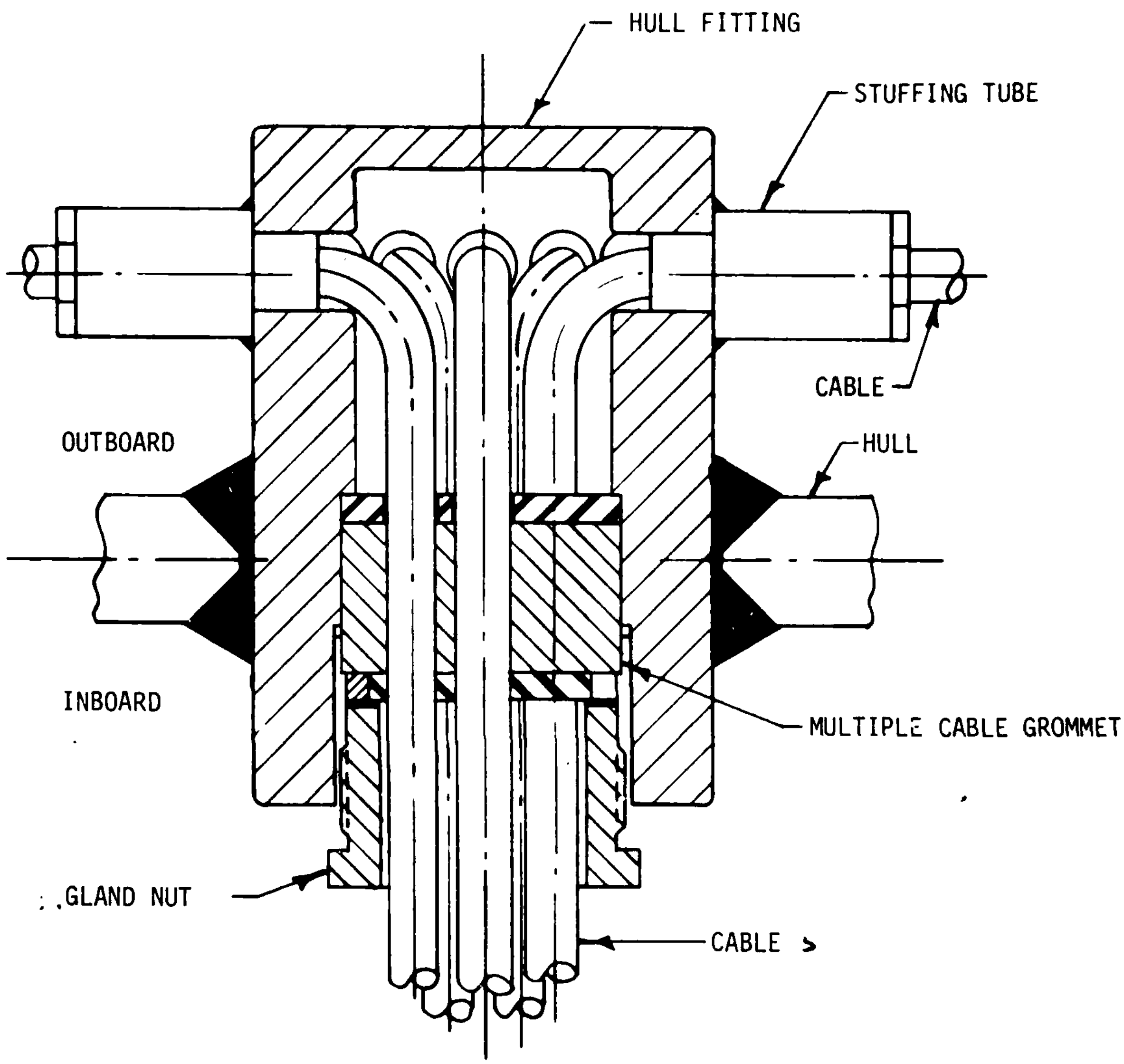


FIGURE 5-20 MULTIPLE CABLE STUFFING TUBE HULL PENETRATOR

5.15 MIL-C-22249 Missile Tube Penetrator

MIL-C-22249 missile tube electrical penetrator designs are basically composed of a receptacle header assembly and missile and compartment side plug assemblies. As seen in Figure 5-21, the type 316 corrosion resistant steel header assembly is located in the missile tube insert. The header is fitted with double ended glass sealed and insulated pin contacts to provide the necessary conductor water barrier. The header is double O-ring sealed to the tube insert and retained with a locking nut. A pin polarizes the header to the tube insert. The right angle plugs located on each side of the header assembly are fabricated from type 316 stainless steel. The plug coupling nuts are manganese bronze. The socket contacts in the plugs are insulated and retained in a diallyl phthalate plastic insulator assembly. The plugs are double O-ring sealed the header and the cables are sealed and fastened to the plug assemblies with molded polyurethane boots. The penetrators are not normally in a sea water environment. They provide a water barrier when the tube is flooded. They also provide a necessary interface between the missile manufacturer and the shipbuilder. The MIL-C-22249 penetrator designs are available in 3 to 208 contact arrangements, (3, 6, 12, 15, 19, 44, 72, 175, 208 contacts).

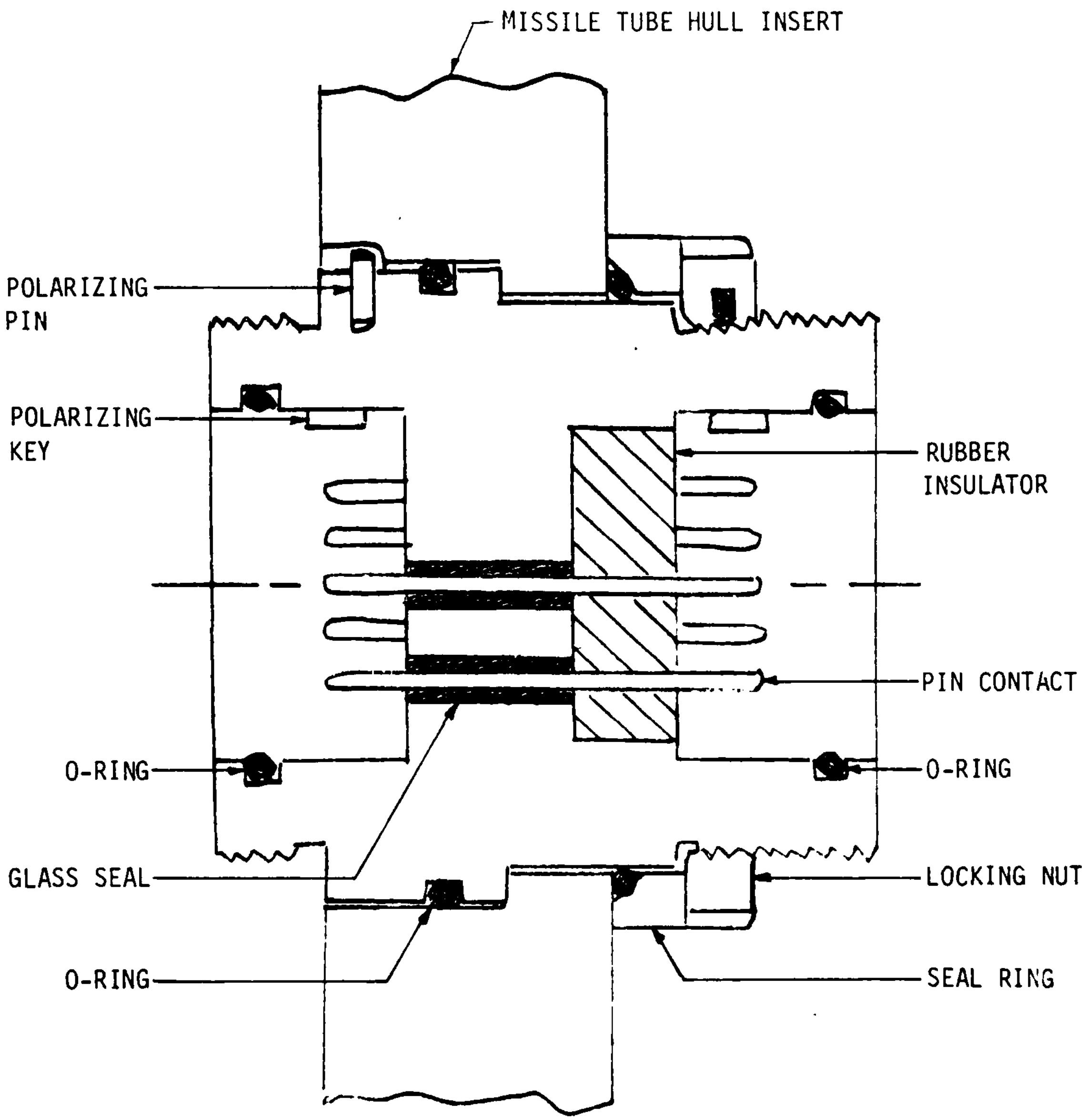


FIGURE 5-21 MIL-C-22249 MISSILE TUBE PENETRATOR

5.16 ALVIN Hull Penetrator

The ALVIN electrical hull penetrator currently used is shown in Figure 5-22 and discussed in Reference 5-22. The hull penetrator is a single cable type suitable for oil filling the cable internals. The body is fabricated from titanium (6AL-4V-EL1) and is tapered for a metal-to-metal fit in the hull insert. The metal-to-metal fit provides a pressure-proof seal without the use of the external waterseal gasket. The waterseal gasket is used, however, as a secondary seal. An inboard retaining nut is used to fasten the penetrator to the hull. Two headers are located internally to seal the conductors passing through the penetrator. ALVIN engineers make every attempt to minimize the use of electrical connectors as they are felt to reduce overall reliability of the circuitry. An oil compensated outboard cabling system is felt to provide a more reliable, lighter system than can be obtained by other design options. The internal titanium headers have shouldered contacts that are sealed and insulated with a plastic insulator bushing to provide a waterblock. The headers are O-ring sealed to the penetrator body. A double ended socket contacts (female) provide electrical connection between the pin contacts located in the headers. The socket contacts are held in a plastic insulator assembly. The oil filled jacketed cable is sealed to the penetrator body with a 90^{o} molded neoprene rubber boot. The penetrator assembly accommodates 18 No. 16 AWG conductors and 2 No. 18 AWG shielded twisted pairs.

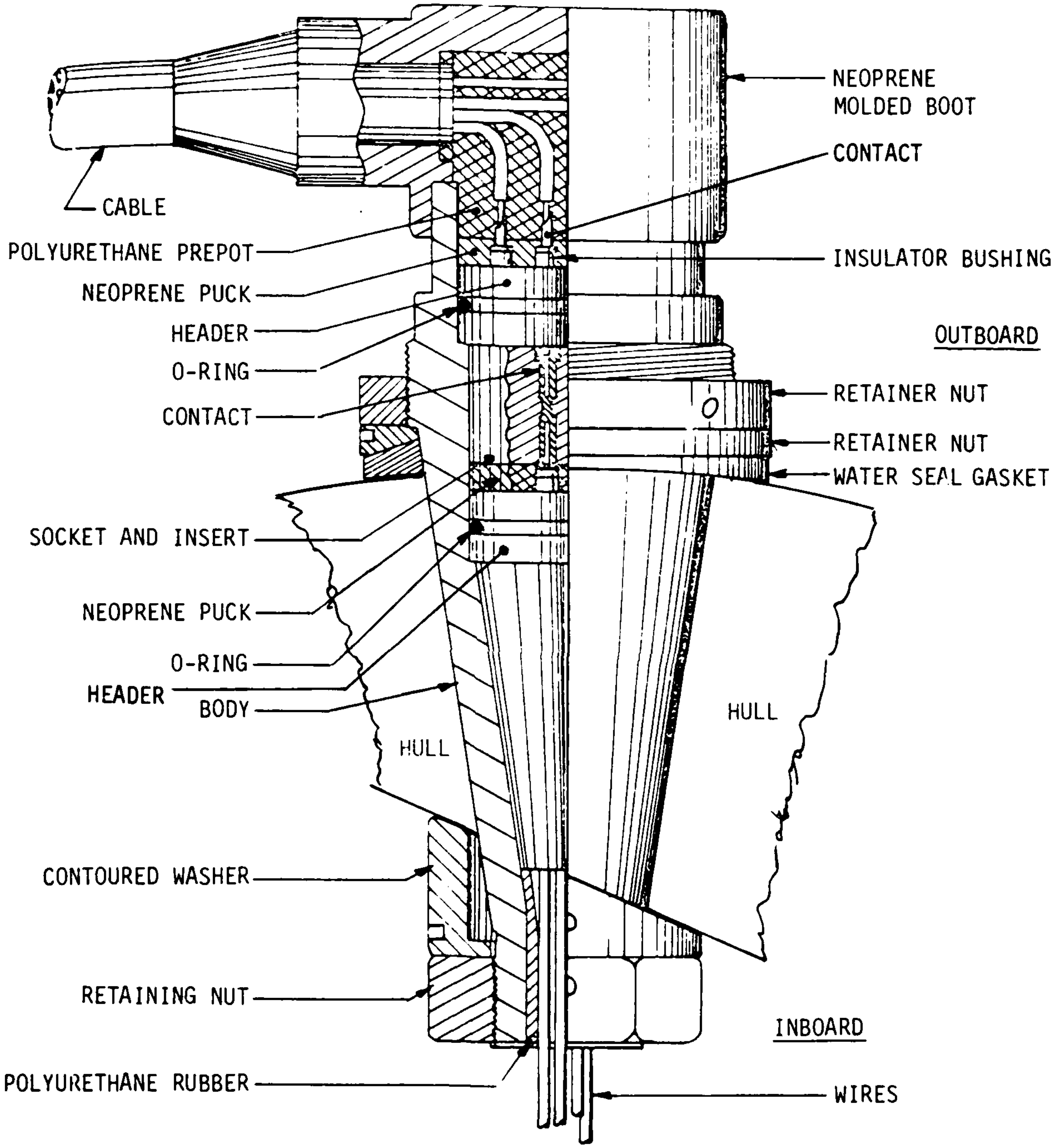


FIGURE 5-22 ALVIN TITANIUM HULL PENETRATOR

5.17 Submarine Coaxial-Cable Hull Penetrator

Coaxial cable hull penetrators currently used on submarines are primarily the designs shown on figure 5-23 and detailed in Reference 5-23. The assembly basically consists of a K-Monel stuffing tube body which houses the coaxial cable as it passes through the pressure hull. The cable jacket and the dielectric are sealed to the stuffing tube with O-ring gaskets. A large non-standard O-ring is used to seal the cable jacket. As seen in figure 5-23, the coaxial cable outer conductor is terminated (grounded) to the stuffing tube on the outboard and inboard sides of the hull penetrator. The braid is retained between the manganese bronze cable seal nut and a retainer on the outboard side. A clamp, washer and nut are used to retain the braid on the inboard side of the penetrator. The coaxial cable has a clamp on the outboard side to provide strain relief. Split dielectric rings and a clamp are used to clamp the cable dielectric on the inboard side of the penetrator. The stuffing tube body has the same overall configuration as the standard MIL-C-24231 hull penetrators. As a result, the stuffing tube is installed in standard MIL-C-24231 hull inserts. The body is double O-ring sealed to the hull insert and retained in the hull with a nut located inboard. A set screw and nylon insert are used to lock the nut to the stuffing tube. The coaxial cable is terminated close to the penetrator on the inboard end as the cable jacket and water braided conductor must be removed to install the cable in the penetrator. The nomenclature for these type hull penetrator are MX8208 through MX8213. These penetrators are functionally identical to the MX2327/U, MX2326/U and MX2646/U types. The penetrators accommodate RG-14A/U, RG-293/U, RG-17A/U, RG-57A/U and RG-294A/U coaxial cables. These hull penetrators have replaced previously used types which had the stuffing tube body directly welded to the pressure hull. These still bodied penetrators suffered corrosion problems in the O-ring seal areas. Reference 5-24 provides the necessary procedures to assemble these as well as other coaxial hull penetrator designs.

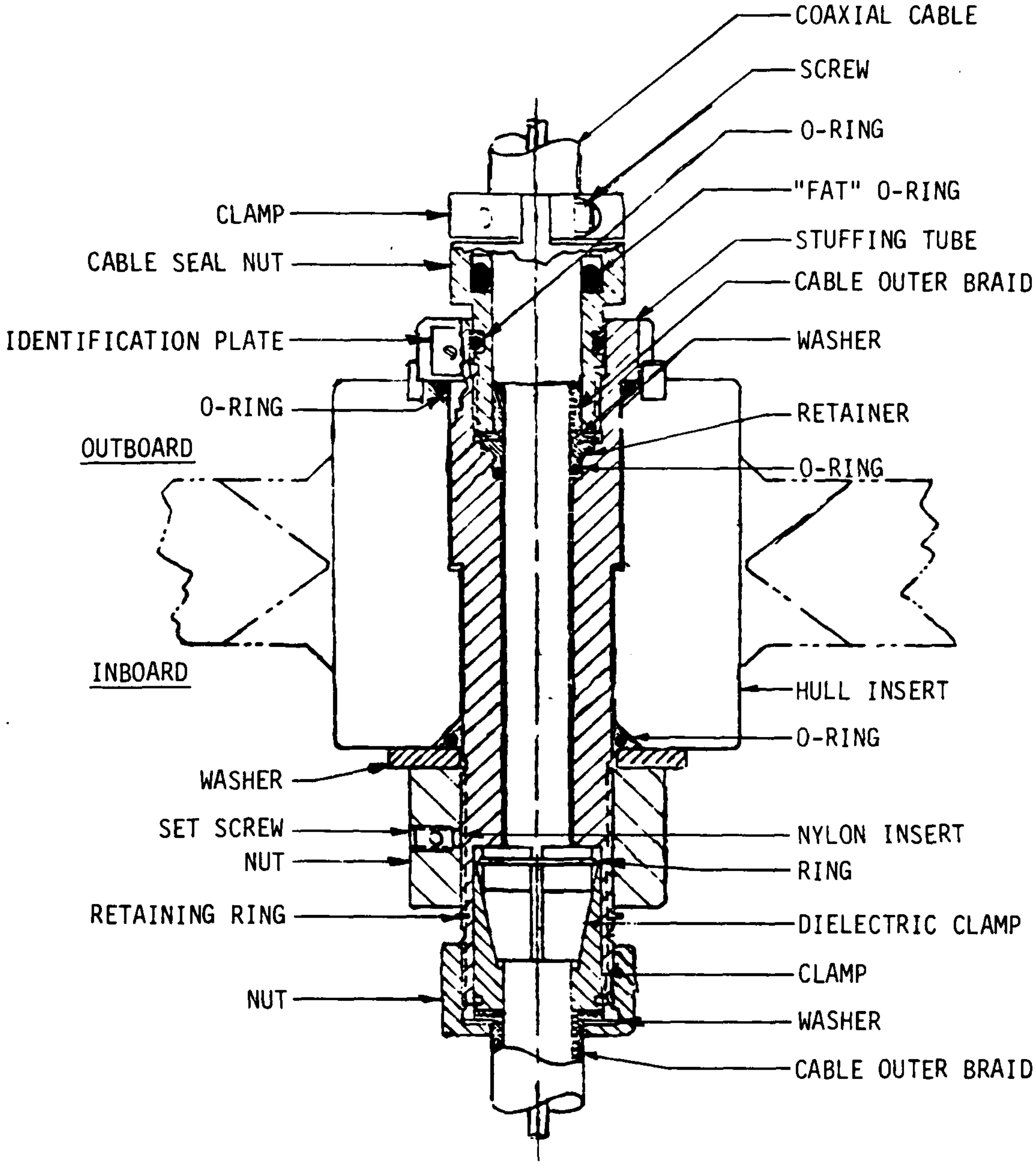


FIGURE 5-23 SUBMARINE COAXIAL CABLE HULL PENETRATOR

REFERENCES

5-1 MIL-C-24231 (SHIPS), "Connectors, Plugs, Receptacles, Adapters, Hull Inserts and Hull Insert Plugs, Pressure-Proof".

5-2 NAVSEA Drawing 815-1197218, "Hull Fitting for AN/BQQ-1 Sonar (Sym-538)".

5-3 Raytheon Company Drawing No. 939333, "Penetrator Assembly".

5-4 General Electric Company Drawing No. 77D607622 Group 1 "Hull Penetrator Assembly".

5-5 Electric Boat Division Specification CPG 1022, "Penetrator, Electrical, TRIDENT Submarines".

5-6 Electric Boat Division Specification CPG 1025, "Penetrator, Connector Type, Electrical, TRIDENT Submarines".

5-7 NAVSEA S9601-AA-MMA-010/SSBN-726 Class, "Technical Manual - Maintenance and Repair Instructions for Pressure Hull Electrical Penetrators and Associated Outboard Components".

5-8 MIL-S-24235 (SHIPS), "Stuffing Tubes, Metal, and Packing Assemblies for Electric Cables, General Specification for".

5-9 NAVSEA Drawing No. AGSS555-349-2101317, "Hull Fitting "T" Assembly", (Multi-Connector)".

REFERENCES

(Cont'd)

5-10 NAVSEA Drawing No. AGSS555-349-2101319, "Hull Fitting "X" Assembly", (Single Connector)".

5-11 Electric Boat Division Drawing No. EB-100738, "Hull Fitting, Electrical, Watertight, Submarine, (Multi-Connector)".

5-12 Electric Boat Division Drawing No. EB-100859, "Hull Fitting, Electrical, Watertight, Submarine, (Multi-Connector)".

5-13 Lockheed Specification RV-S-0259, "Thru Hull Connectors, Electrical, Deep Submergence".

5-14 NAVSEA Drawing AUTEC-100-2474975, "Electrical Hull Fitting (AUTEC)".

5-15 NAVSEA Drawing No. DSV4-803 5155923, "Development Specification for Penetrator, Electrical, Sea Cliff (DSV-4), 20,000 Foot Modification".

5-16 D.G. O'Brien, Inc., Drawing C40D5001G, "Hull Penetrator for DSV 4 Modification - 24 No. 16".

5-17 Electric Boat Division Drawing CPG 1318/1 "Electrical Hull Penetrator - 120 Conductors for RAPLOC Program".

5-18 Electric Boat Division Drawing CPG 1410/1, "Electrical Hull Penetrator 240 Conductors for RAPLOC Program".

REFERENCES

(Cont'd)

5-19 Werth, D.A., "High Pressure Titanium Electrical Connectors", Bendix Corporation, Sidney, NY 13838.

5-20 U.S. Patent No. 3,803,875, "Method of Forming Titanium Metal-Glass Hermetic Seals".

5-21 Electric Boat Division Specification CPG 1138, "Proposed Military Specification, Penetrators, Electrical, Deep Submergence Vehicle".

5-22 Hosom, D.S., et al, "Alvin Titanium Electrical Penetrator Design, Manufacture and Testing: Interim Report" Woods Hole Oceanographic Institute, April, 1976.
ONR Contract N00014-73-C-0097.

5-23 NAVSEA Dwg No. SS-302-2477255 "Bolt-In Stuffing Tube - Assembly and Details".

5-24 "Handbook for Submarine Antenna Improvement Program" Naval Underwater Systems Center, New London, Ct. Document No. NUSC No. 551.

SECTION 6

PRESSURE-PROOF ELECTRICAL CONNECTOR DESIGN

LIST OF FIGURES

LIST OF TABLES

6.1 Introduction

Pressure-proof electrical connectors are designed for operation in a seawater environment. The connectors allow the passage of electrical conductors through enclosure walls of pressure-proof underwater electrical/electronic components. The connector also provides a cable seal at the pressure-proof enclosure. An electrical connector assembly is made up of a plug and receptacle connector. The plug is usually wired to the cable and the receptacle is fixed to the enclosure. The pressure-proof electrical connector provides a needed harness disconnect point at the outboard component and the hull penetrator. The pressure-proof receptacle mounted to the component enclosure ensures sealing inside the component should a failure occur in the harness. Other reasons for using electrical connectors are as follows:

a. Provide an interface between the electrical/electronic component manufacturer and the vehicle manufacturer and user.

b. Provide a convenient electrical test point for the component.

c. Allows proper packaging of the component for handling, packing, shipping, storage, and installation.

d. Eliminates the need for the component manufacturer to provide the electrical cable to a distant, unknown junction point.

e. Provides a proper interface for the maintenance and replacement of components and cables.

f. Provides an interface between components in a complex system.

g. Facilitates the manufacturing and assembly process of components.

h. Allows the hermetic or watertight sealing of an electrical component package.

i. Facilitates the hydrostatic pressure testing of outboard electronic components or electrical penetrators.

The heart of the connector is the pin and socket contacts. These two components make the electrical junction. Although in standard non-pressureproof designs, these contacts may be located in either the plug or receptacle; pin contacts are normally located in the receptacle, and socket contacts in the plugs in pressure-proof connector designs.

Most underwater connectors in use today can be divided into three types based on construction material, and can be described as follows:

a. Metal plug and receptacle.
b. Molded rubber plug and receptacle.
c. Plastic plug and receptacle.

<u>NOTE</u>

UNDERWATER MATEABLE (MAKE AND BREAK) CONNECTORS AND THEIR DESIGNS ARE NOT COVERED IN THIS HANDBOOK AS THEY ARE NOT CURRENTLY USED IN SONAR SYSTEMS OF TACTICAL SUBMARINES. THEY ARE USED IN A LIMITED NUMBER OF CASES IN DSV'S AND ARE BEING CONSIDERED FOR USE IN FUTURE TACTICAL SUBMARINE SYSTEMS.

6.2 Electrical Connector Types

This section discusses the recommended pressure-proof connector designs as well as design factors for connectors which must be considered in any connector development program.

6.2.1 Metal Shell Connector - The metal construction which provides a rigid skeleton has demonstrated the greatest degree of reliability on submersible equipments. See Figure 6-1. The nature of the design requires more component parts, is heavier and has greater initial cost. However, these disadvantages are more than compensated for by its higher degree of reliability and its resistance to installation and environmental damage. The added initial cost becomes insignificant when related to the overall system cost and the critical role a connector plays in a system's satisfactory function. A single connector failure can cause an entire system failure and abort a mission.

The metal plug shell provides a rigid and adequate bonding surface for the cable seal and thus provide adequate cable strain relief at this point. The rigid construction makes possible a greater degree of wire position control in molding a cable to the plug, and therefore, much less chance of electrical shorts or open ends due to uncontrolled migration of conductors during the cable end sealing process. The metal shell provides a positive stop for controlled gasket squeeze in seal areas between plug and receptacle and between receptacle and mounting surface. Metal has the necessary strenth and dimensional stability to provide reliable threaded parts. A metal receptacle shell provides the necessary support for a positive and reliable pressure barrier in case of accidental exposure to sea pressure. Metal construction provides for a more reliable mounting of bulkhead

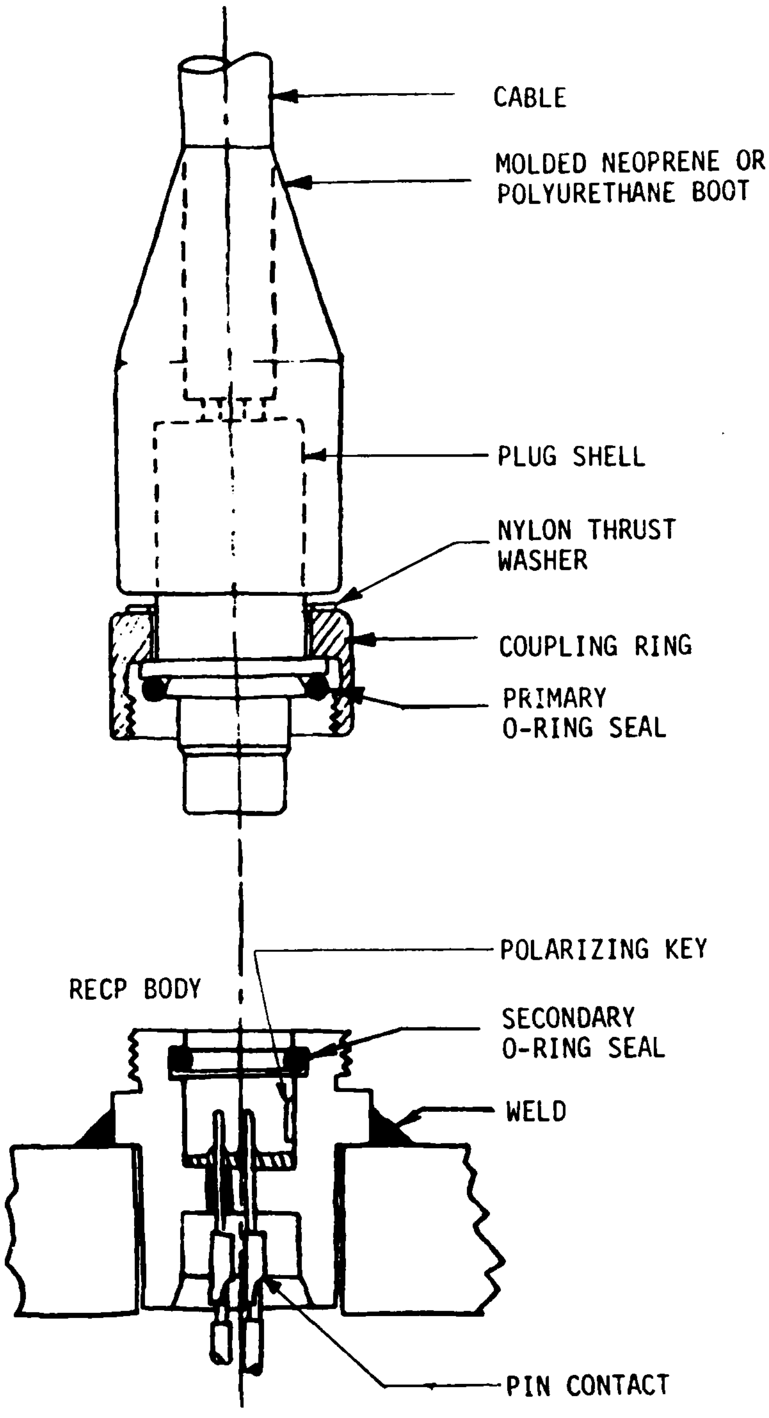


FIGURE 6-1 METAL SHELL CONNECTOR

types and an additional mounting method: a seal weld. An individual insulator in combination with snap-in socket contacts provides good contact positioning with adequate flotation for proper mating alignment. Metal bodies are best adapted for a positive keying arrangement to polarize plug with receptacle. Where both plug and receptacle shell are of a non-resilient material, a more reliable coupling can be accomplished. Elastomer compression set and material flow with resulting loosening is not a problem.

Insulating components must be provided for electrical isolation of the conductors. Means of securing and sealing these parts must also be provided. Applications that require the metal connector to be subjected to a considerable degree of pressure cycling call for special attention to the manner of wiring and how the conductors are supported in the back end of the plug between the cable end seal and conductor termination. Otherwise, fatigue failure of the conductor can occur. Where non-resilient parts interface at plug and receptacle, a minimum volume void is always present because necessary dimensional tolerances preclude interfacial contact at this point. This void can account for some electrical degradation due to condensation of moisture in contact area. This can be significant depending on application and environmental temperature and humidity ranges. Contact insulation composed of compression glass seals must be adequately protected from welding temperatures when components are fastened or sealed by this method.

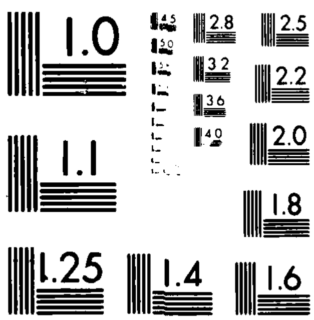
Disadvantages of the metal type connector include the need for additional individual contact seals which are inherent in the integrally molded rubber type connector. Sealing surfaces are subject to damage causing possible seal failure. Metal parts are subject to varying degrees of corrosion depending on material choice and environment. This condition can be compounded by other interfacing metals and/or stray electrical currents.

AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

UNCLASSIFIED NRL-MR-4601 NL

3 OF 8
AD
A111931

1193



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

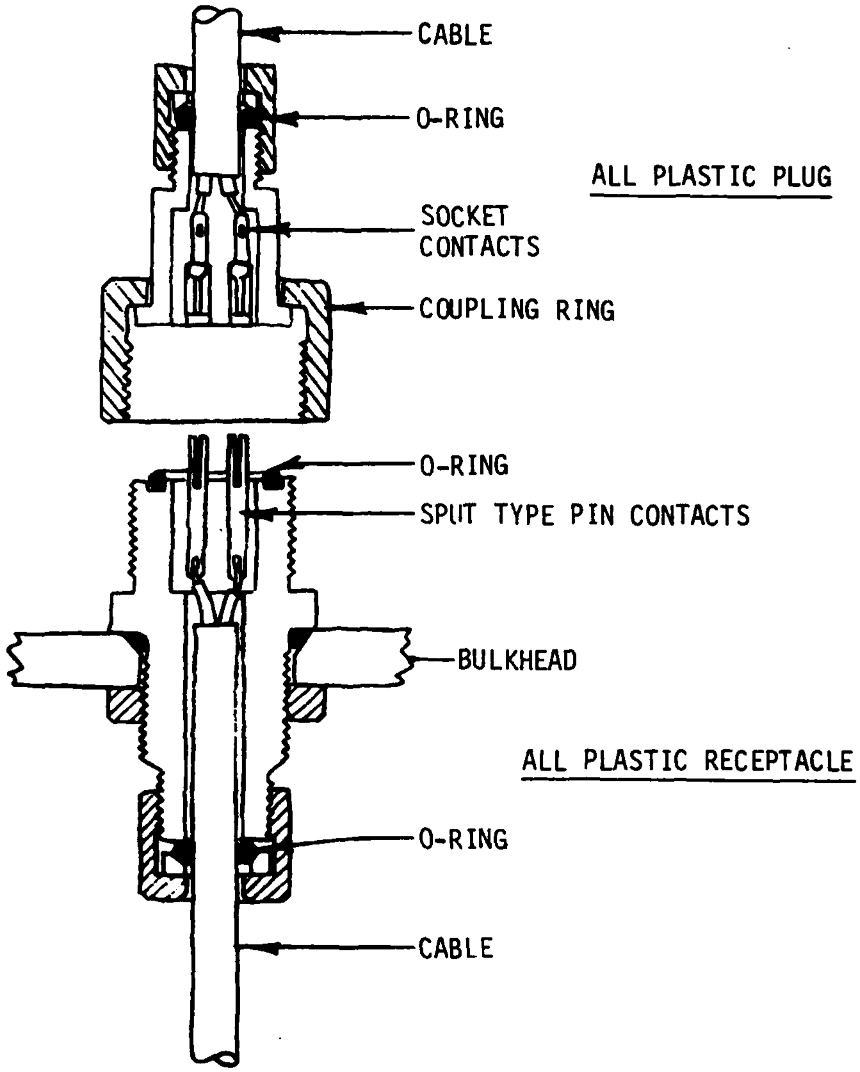
6.2.2 Molded Plastic Connector - The molded thermosetting resin type of connector construction, Figure 6-2 is relatively inexpensive and ideally suited to production in quantity. It has many of the same advantages of the all rubber type. These include: fewer components, integral molding requires no internal seals, no insulators are required as the structural material is a good dielectric, the material is not affected by salt water corrosion and cannot form a galvanic couple to damage adjacent metal parts.

However, experience has indicated that plastics have many deficiencies as a connector fabricating material. Any one specific thermoplastic or thermosetting resin material does not seem to combine the desirable electrical properties with all the required physical and mechanical properties necessary for use as a Navy outboard connector. Some of these properties include a high degree of dimensional stability, high impact strength, low mold shrinkage, low water absorption, high compressive strength and non-flammability.

Fabricating requirements further limit the material choice. These include good moldability, with any necessary reinforcing fiber content, at reasonable temperatures and pressures. Some of the more common defects found in molded connector parts include the following: cracks at points of high stress which are generated in the molding process and proliferate with use; threads that fail under load or are damaged by impact; failure in areas that are mold resin rich and lack the necessary fiber content; seal surfaces that do not present the required finish due to excessive flash or porosity; molded connectors exposed to higher levels of pressure cycling have shown evidence of minute fiber displacement followed by fatigue and eventual structural failure.

Plastic connectors can be neoprene or polyurethane molded to underwater cables using a rubber boot which is bonded to the cable jacket and the plastic shell of the connector plug. If neoprene molding is used, then the plastic material must be capable of withstanding the higher neoprene molding temperatures (250-300^{o}F).

The molded plastic connector has exhibited serious design deficiencies to date, especially for higher pressure applications. However, it is not inconceivable that the proper combination of material and design would produce a satisfactory connector for low pressure application. Impact resistance, especially in the molded thread area, has posed the most serious problems to date in plastic connector usage.



<u>NOTE:</u> A FIELD INSTALLABLE CONNECTOR IS SHOWN.

FIGURE 6-2 PLASTIC SHELL CONNECTOR

6.2.3 Molded Elastomer Connector - The molded or cast elastomer connector construction, Figure 6-3, provides the least expensive type of underwater connector. Basically, this type of connector consists of a length of cable whose conductors are teminated with male or female contacts. The entire terminal area is molded or cast integral with the cable jacket. The contacts are positioned by external means until curing or vulcanizing is complete. The geometry of the molded area is such as to provide a sealing interface between plug and receptacle and provide for strain transition between contact area and cable. Due to the resilient qualities of the material used, relatively thick sections are required to provide adequate polarization between plug and receptacle. This results in a large connector. For this reason, polarization, where present in this design, is normally accomplished by contact pattern or two different contact diameters. Either method poses problems because electrical contact between plug and receptacle is possible prior to proper alignment and mechanical locking. For this reason, this type of connector is vulnerable to electrical mismating and contact damage.

The materials most often used in fabricating this connector are neoprene, for pressure molding, and polyurethane for cast molding. The neoprene molded connector is superior in several design areas. However, the inability to properly control movement of the conductor during the pressure molding process can lead to electrical opens and shorts that very often occur after the connector sees the operating environment..

The all rubber type of connector, not having a rigid internal or external structure, does not provide for positive and controlled compression of interfacial seals. For the same reason, most coupling and mounting devices are marginal because the material is subject to compression set. Seal failure can also occur when the connector is mated in a low temperature environment, due to loss of elasticity. Most designs have little or no protection for pin contacts.

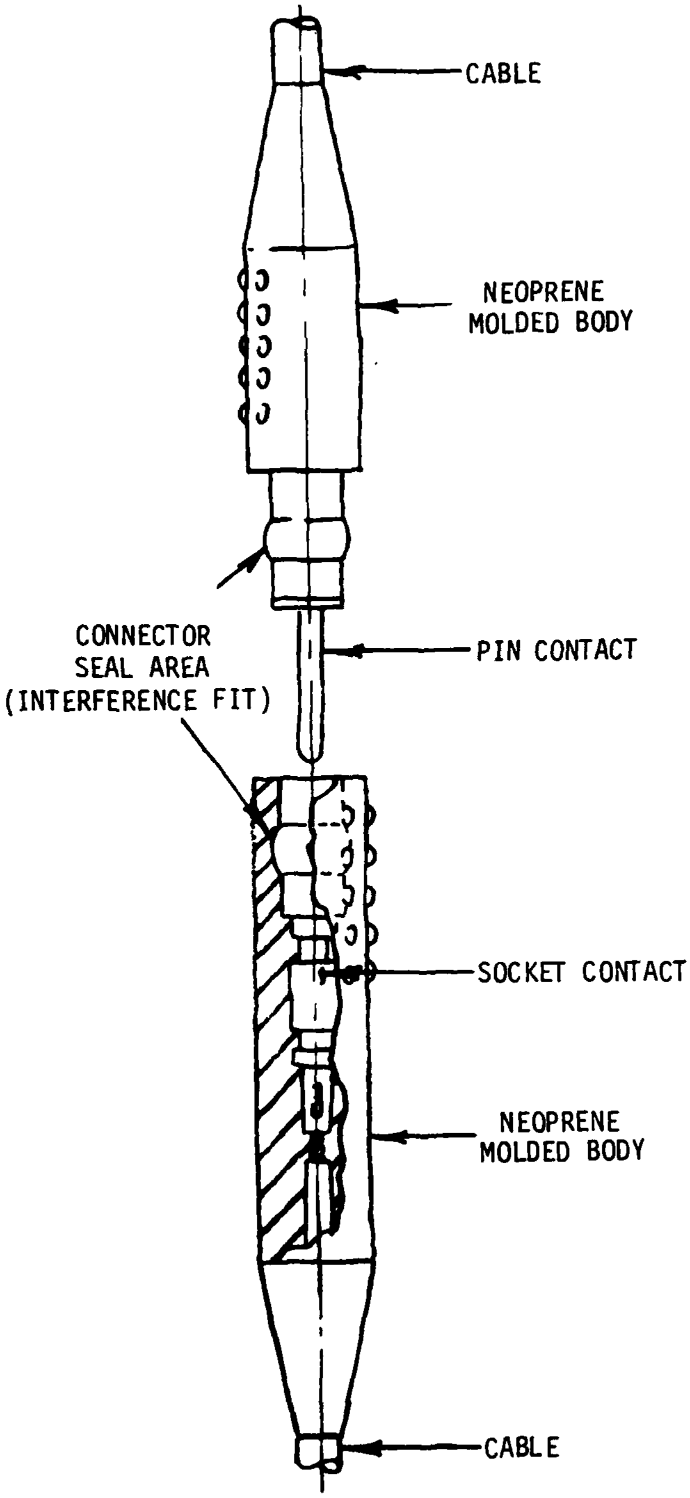


FIGURE 6-3 MOLDED ELASTOMER CONNECTOR

The connector is also subject to failure when the unit is flexed at the conductor-contact interface.

This type of connector construction is not without certain advantages. Among these are low cost, light weight, capability of withstanding considerable abuse, and because it is integrally molded, fewer seals are required. Both plug and receptacle withstand open face pressure equally well. No material corrosion problem exists with this connector type. The material being a dielectric precludes its contributing to galvanic corrosion of adjacent areas. Obviously, no separate insulating parts are required. The resilient material provides for a void-free interface between mated plug and receptacle.

6.3 Connector Design Factors

This section covers the design of electrical connectors. The development of a connector requires the consideration of many design factors. These are listed in Table 6-1 and depicted in Figure 6-4.

6.3.1 <u>Connector Configuration</u> - The connector design should be cylindrical due to external hydrostatic pressure resisting requirements, the relative ease of sealing the cylindrical plug-to-receptacle components, and the ease of fastening offered by cylindrical components. Plugs for straight and right angle cable entry should be developed. The right angle plugs are an undesirable, but necessary component; they are more difficult to fabricate, wire, and mold but in many cases can save valuable space. Right angle plugs are desirable in that the cable has a predetermined travel away from the connector without flexing and causing undue strain at the back of the connector shell. Naturally, connector diameters should be kept as small as practicable for weight and space considerations.

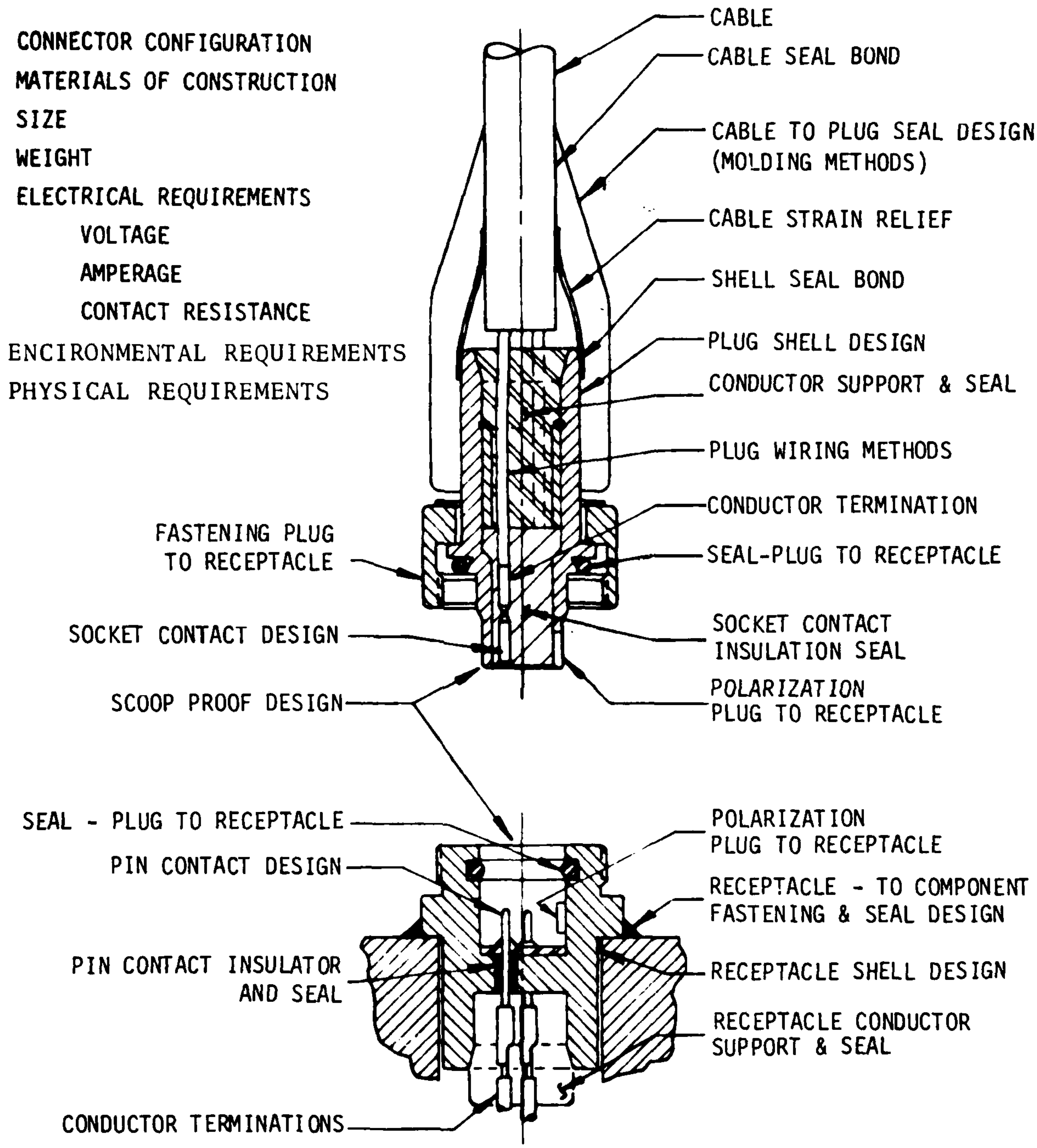


FIGURE 6-4 PRESSURE-PROOF CONNECTOR DESIGN PARAMETERS

TABLE 6-1

ELECTRICAL CONNECTOR DESIGN FACTORS

1. Connector Types and Sizes
2. Configuration - Connector
3. Plug Design
4. Receptacle Design
5. Pin and Socket Contact Design
6. Fastening - Plug to Receptacle
7. Sealing - Plug to Receptacle.
8. Connection - Conductor to Socket Contact
9. Insulation and Seal - Pin Contact
10. Insulation and Seal - Socket Contact
11. Seal - Cable to Plug
12. Electrical Requirements
13. Cable Strain Relief
14. Material Selection
15. Corrosion Properties
16. Fabricability
17. Strength
18. Cost

6.3.2 Connector Types and Sizes - Connector shell sizes should be kept to the smallest number possible. Every effort should be used to make one shell size accommodate more than one pin configuration, but not to the detriment of physical and electrical characteristics of the connectors. Table 6-2 lists the connector contact configurations for MIL-C-24217 and MIL-C-24231 required for recommended cable connectors.

The diametral requirements for connectors in general are dependent upon the size of the electrical contacts and the connector contact complement. With this factor remaining constant for all classes of connectors, the other dimetral considerations are the various hydrostatic pressure requirements.

Proper connector design plays a greater role in determining connector length than does submergence pressure. Major considerations along this line include:

(a) Provide sufficient length for proper engagement of the contacts and for plug and receptable lead in for straight mating of plugs and receptacles.

(b) Make the polarizing key long and strong enough to ensure correct entrance and contact engagement.

(c) Make the plug shell long enough to contain the elastomer boot bond and a hermetic water block with contacts.

(d) Provide enough space for a backshell potting attachment.

TABLE 6-2

MIL-C-24217 AND MIL-C-24231 CONNECTOR SHELL AND CONTACT TYPES AND SIZES

MIL-C-24231

Shell Size	No. Of Contacts	Contact Size
A	3-4-5	16
B	7-8-9	16
C	14-24-30-40	16

MIL-C-24217

A	3	16
B	5	16
	3	12
C	9	16
D	14	16
	3	8
E	24	16
	9	12
	3	4
	6	3/8 - 3/12
F	37	16
	6	2/0 - 4/12
G	48	16
H	5	12

6.3.3 Plug Design - The plug should be cylindrical and, in most cases, should house the socket contacts, sealed and insulated in a plastic or elastomeric housing. The plug should have a threaded coupling ring and house the necessary plug-to-receptacle seal. A plug-to-receptacle polarization keyway or key should be provided. The necessary conductor strain relief device should be designed to withstand the full hydrostatic pressure loading as should the plug shell flange which is bottomed against the face of the receptacle. Material selection is a primary consideration in the plug design.

Socket contacts should be located in an insulating material inside the plug. This provides support for contacts and conductors when they are subjected to high hydrostatic pressure loading. Tests conducted by the USN have shown this area to be one of the most critical in the design of a pressure-proof connector. Cyclic hydrostatic pressure loading of connectors has resulted in Z kinking and fracture of conductors inside the plug shell. See Figure 9-3. These conductor failures have been attributed to the use of low bulk modulus potting materials such as neoprene, or voids existing inside the plug shell allowing the conductors to bend and subsequently break. As a result, much design attention must be focused in the connector-cable interconnection area. The use of filled epoxy compounds is felt to be mandatory to provide the proper structural support for the conductors at deep submergence pressures.

All plug shells should have a feature enabling them to adapt to either a right angle or straight cable support.

A positive water barrier in the plug assembly is recommended. Should the cable be damaged or severed, then water will course up the cable only to the barrier in the plug. As a result, the receptacle-plug interface will remain unaffected.

6.3.4 Receptacle Design - Receptacles should be cylindrical. This shape is least expensive to machine and lends itself to fastening and sealing more readily than other configurations. Also, glass sealing manufacturing procedures are better adaptable to circular receptacles. The receptacle should house one plug-to-receptacle seal and provide a sealing surface for the second seal. It should also provide a thread for fastening the plug to the receptacle. Polarizing keys for the plug/receptacle assembly relationship should be a part of the receptacles. A water barrier should be provided for in the receptacle at the contact web section to prevent water from entering the component. The receptacle design must be such that the receptacle web section can be hydrostatically tested prior to shipment by the fabricator. The receptacle or plug contact water barrier which may be inadvertently exposed to sea water should withstand a test pressure in the exposed condition of at least one and one-half times the maximum operating pressure. Receptacles and plugs in which the contacts are compression-glass sealed very effectively satisfy this requirement. Methods of fastening receptacles to components should be by use of a bolted flange, welding, or by a lock nut and flange. See Section 7. There should be a backup seal for every primary seal used in sealing a receptacle to a component. This is not necessary, however, if the receptacle is welded to the component housing.

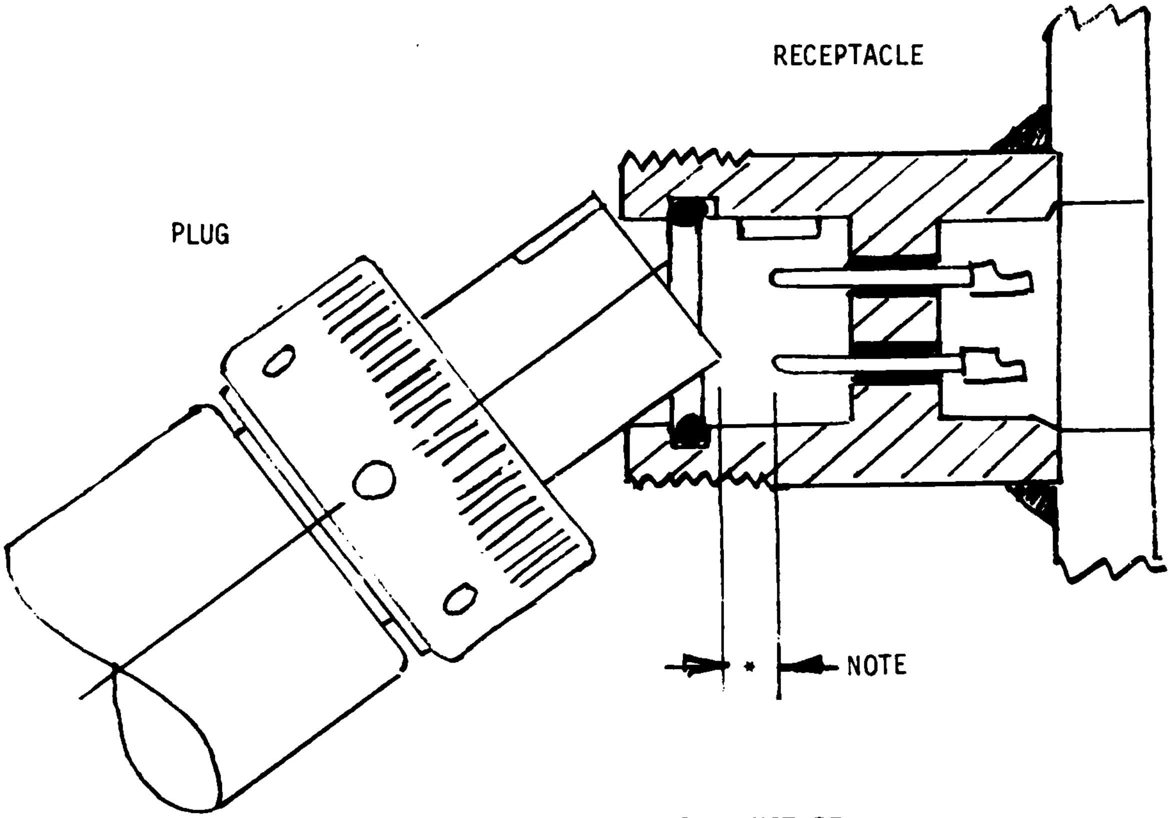
With respect to the plug-to-receptacle mating sequence, the following mating sequence steps are recommended:

(a) The plug is polarized to the receptacle with the use of keys and keyways. There is neither pin-socket electrical contact engagement at this juncture; nor coupling of the plug to the receptacle.

(b) The plug and receptacle having been polarized, the plug coupling ring now engages the threads of the receptacle.

(c) As the coupling ring is fastened to the receptacle, the pin contacts begin engaging the socket contacts, and electrical engagement takes place between the pin and socket contacts.

Another important requirement in the plug receptacle design is the need for a scoop proofness. As seen in Figure 6-5 the plug shell should not be capable of contacting the pin contacts in the receptacle under any other than properly aligned mating conditions. This is especially important for the smaller sizes contacts such as 20 or 16 AWG. Scoop proofness prevents the possibility of bending or otherwise damaging receptacle pin contacts.



* NOTE: PLUG SHELL SHOULD NOT BE CAPABLE OF STRIKING PIN CONTACTS IN RECEPTACLE WHEN INSERTED OFF-AXIS.

FIGURE 6-5 SCOOP-PROOF CONNECTOR REQUIREMENT

6.3.5 <u>Material Selection</u> - Selection of plug, receptacle shell and coupling ring materials is one of the most important design decisions to be made. The materials used affect the size, weight and projected life of the components. The most desirable materials are those with high corrosion resistance. Materials of construction should provide inherent resistance to electrolytic corrosion resulting from stray leakage current. Very slight differences in potential can erode relatively thick metal sections in a very short period of time. The possibility of a critical degree of galvanic coupling must be considered when making a material choice for the connector parts. Areas that interface with each other should be such as to prevent entrapment of seawater which may lead to crevice corrosion. Non-metallic materials can also be considered. Although the mechanical properties of most of the plastics cannot be compared with metals, many do offer excellent corrosion resistance as well as weight savings. Some of their limitations, however, include relatively low impact strengths as well as poor moisture absorption and aging characteristics.

Table 6-3 is a listing of specific gravities of materials which can be considered in connector design.

6.3.5.1 *Corrosion Resistance* - When considering metals for high pressure connector shells, Monel, K-Monel, Inconel 625, Titanium, ARMCO NITRONIC 60 stainless steel, Hastelloy C, and type 316 stainless steel are known to offer good corrosion resistance in a sea water environment. All of the above materials also offer tensile strength properties in excess of 60,000 psi except Monel and 316 stainless steel. It should be noted that class 316 stainless steel can suffer from pitting corrosion in ungrounded submerged applications. The material has, nevertheless, seen wide successful use in marine applications over the years where it is grounded to a steel hull. References 6-1 through 6-10 provide additional data on the selection of materials for these applications.

6.3.5.2 *Fabricability and Cost* - Metal connectors are the most expensive types due to material and machining costs. Molded plastic connectors should cost approximately one half the metal types. Molded rubber connectors should be less costly than plastic connectors. They offer the best advantage of molding the cable to the connector at the same time the connector is molded. Properly wiring and seal molding a cable to the plastic and metal connectors is a time consuming and costly operation which is not normally considered in the connector cost. It is considered when fabricating a cable harness assembly.

TABLE 6-3

Approximate Specific Gravities of Materials

Substance	Specific Gravity
Hastelloy C	8.95
Cupro-Nickel (70-30)	8.94
Monel	8.84 - 8.48
K-Monel (Ni-Cu-Al)	8.49
Inconel 625	8.44 - 8.08
Cr-Ni-Fe Superalloy	8.17 - 7.88
Stainless Steel (Aus)	8.02 - 7.75
216 SST	7.95
Armco 22-13-5 Stainless Steel	7.9
17-4 PH Stainless Steel	7.79
Stainless Steel (Fer)	7.75 - 7.47
Stainless Steel (Mar)	7.75
Titanium	4.73 - 4.43
Epoxies (Cast) Ht Res	3.2 - 1.15
Phenolics (molded)	3.0 - 1.24
Aluminum Alloy 6061	2.71
Epoxies (Cast) GP	2.4 - 1.12
Melamine	2.0 - 1.43
Epoxies (molded)	1.85
Diallyl Phthalate (Gl)	1.59 - 1.55 (1.63)
Polysulfone 40% GF	1.55
PVC	1.55 - 1.16
Nylon Tape 6/6 40% GF	1.52
Nylon, Glass Filled	1.51 - 1.30
Polycarbonate 40% GF	1.51
Acetal 20% GF	1.53
Polycarbonate	1.51 - 1.20
Styrene Acylonitrile (S.A.N) 33% GF	1.46
Polyesters (Cast)	1.46 - 1.06
Acetal	1.43

TABLE 6-3

(Cont'd)

Substance	Specific Gravity
ABS Resin 40% GF	1.38
Polyphenylene Oxide (PPO) 30% GF	1.27
Neoprene Rubber	1.25 - 1.20
Silicone, Urethane Rub.	1.25
Phenolics (Molded)	1.24 - 3.0
Nylon 6, 11, 66 and 610	1.14 - 1.09
ABS Resins	1.07 - 1.01
Polyethylene (AD)	0.96 - 0.94
Polyethylene (MD)	0.94 - 0.93
Natural Rubber	0.93
Polypropylene	0.91 - 0.90
Butyl Rubber	0.90

The specific gravity of a solid or liquid is the ratio of the mass of the body to the mass of an equal volume of water at some standard temperature.

To obtain density in lb/cubic inch, multiply by 0.0361. To obtain lb/cubic foot, multiply by 62.43 (from Reference 6-11). Multiply by 10 to obtain kilograms per cubic meter.

6.3.6 Pin and Socket Contact Design - Pin and socket configurations, specific resistivity of materials, plating, dimensional tolerances, surface finish, corrosion resistance hardness of metal and conductor termination and design are all important considerations in the development of an electrical connector. Contacts should have low specific resistivity and should approach the current carrying capability of copper (See Table 6-4). Pin and socket contacts in the sliding area should be gold plated in accordance with MIL-C-45204 and underplated with a copper flash. Surface finishes are to be smooth to ensure a mating action which will not tear or scratch the contact and at the same time provide maximum surface engagement between the pin and socket contact. Every effort should be made to use standard contact configurations. The most logical choice is MIL-C-39029. These contacts should be used with standard MS crimping tools per MIL-C-22520. Where glass insulation is used, the glass-sealed contacts should be fabricated from molybdenum or steel. Brass and bronze should be used when pressure requirements do not call for the glass or ceramic insulations. Molybdenum is preferred over the conventional mild steel because the contact resistance is lower and the pins are stiffer and not so easily bent or damaged. When glass-insulated pins required the use of solder pots, they should conform to the requirements of MIL-C-5015. Contact sizes larger than 16 size should conform to the requirements of MIL-C-5015. Table 6-5 gives the contact pin diameters that should be used in all connector groups.

TABLE 6-4

ELECTRICAL RESISTIVITY OF METALS

Material	Electrical Resistivity (Micro OHM - CM) High	Low
Silver	1.59	
Copper	2.03	
Gold	2.35	
Commercial Bronze-90% Annealed	3.90	
Red Brass-85% Annealed	4.70	
Rhodium	4.51	
Beryllium	5.00	
Molybdenum	5.17	
Low Brass-80% Annealed	5.40	
Tungsten	5.48	
Beryllium Copper	5.82	4.82
Cartridge Brass-70% Annealed	6.20	
Aluminum and its Alloys	6.30	2.80
Yellow Brass, Annealed	6.40	
Leaded Brasses	6.60	4.10
Palladium	10.80	
Free Cutting Steels	14.30	
Platinum	14.90	
Phosphor Bronze	16.00	3.60
Magnesium Alloys	17.00	5.00
Carbon Steels	19.00	14.30
Cupro-Nickel	37.00	15.00
Ferritic Stainless	72.00	40.00
Martensitic Stainless	67.00	60.00
Austenitic Stainless	78.00	69.00
Titanium and Alloys	176.00	90.00

(From Reference 10).

TABLE 6-5

PIN CONTACT DESIGN INFORMATION

Contact Size	Pin Diameter (Inches ± .001)	Stranded Wire Sizes Accommodated In Crimp Barrel
4/0	.500	4/0 - 2/0
1/0	.357	1/0 - 2
2	.238	2 - 4
4	.225	4 - 6
6	.178	6 - 8
8	.142	8 - 10
10	.125	10 - 12
12	.094	12 - 14
16	.0625	16 - 20
20	.040	20 - 24
22	.030 ± .0005	22 - 24
23	.027 ± .0005	22 - 24
24	.025 ± .0005	24 - 26
26	.020 ± .0005	26 - 28
28	.015 ± .0005	28 - 30

6.3.7 Connection-Conductor to Socket Contact - The cable conductors can be electrically connected to the socket contact pins by solder, crimp, or taper pin insertion. All of these methods are compatible with the connector design, considered from a space viewpoint. Welded, clamped, or wire wrap methods are not seriously considered because of the relatively large space required to make a multi-contact assembly.

The primary requisite for the selection of a connection in this design is good conductivity and mechanical strength. The mechanical aspects of the joint are critical, since the connection is subject to mechanical stresses during actual service conditions.

Soldering is the most widely used method for making electrical connections. Electronic component manufacturers are agreed that the reliability of a soldered joint depends on the man who makes the joint. If he follows accepted soldering procedures then a good joint will result.

In the past two decades, crimped electrical connectors have come into general use. In this design, a contact is precisely crimped to a conductor with a special crimping tool; each connection can be made the same way each time. For these reasons the use of crimp joint connections is recommended where practicable.

Cable shields should be terminated with inner and outer crimp ferrules with pigtails terminated at the contacts. This military standard system has proved most adequate over the years in all cable connector environments. The ferrules are detailed on MS 21980 (ASG) and MS 21981 (ASG). Also, the Raychem Corporation solder sleeves are considered acceptable for terminating cable shields.

All wire terminations within the plug or receptacle cavity at the rear should be sealed and supported. This combined moisture barrier and strain relief is readily accomplished by potting compounds.

6.3.8 Fastening - Plug to Receptacle - Of the coupling mechanisms to be considered for fastening the plug to the receptacle, the two most used in the connector industry for cylindrical connectors are threaded and bayonet- type coupling rings. Other types used with rack and panel type connectors do not apply here. Due to plug-to-receptacle sealing considerations, the threaded coupling ring offers the most positive fastening and sealing mechanisms for underwater use. A tool, however is required to ensure proper mating of the plug and receptacle and to prevent loosening under vibration and impact shock conditions. This coupling mechanism has proven satisfactory in past years as very few connector matings are made during the life of an assembly. Bayonet-type coupling rings are normally best used in quick disconnect applications, such as are required with laboratory test equipment where many matings are required during the life of the components. They are not recommended for use on submarines and surface ships.

Mated receptacles and plug/cable harnesses should be able to withstand a high impact shock test and a vibration test without physical damage or significant discontinuities in the electrical circuits and/or loosening of mated component parts.

Consideration should be given to the use of stub Acme and the standard V threaded design for threaded coupling rings. The coupling ring material is chosen for its corrosion resistance, weight, and galling and seizing properties. A hook or pin type spanner wrench should be used to operate the coupling ring. The coupling ring for the pressure-proof connectors should be fabricated from a corrosion resistant material which will not gall and seize when threaded to the Monel or Type 316 stainless steel receptacle body material. Nickel aluminum bronze coupling rings have proven satisfactory in this application.

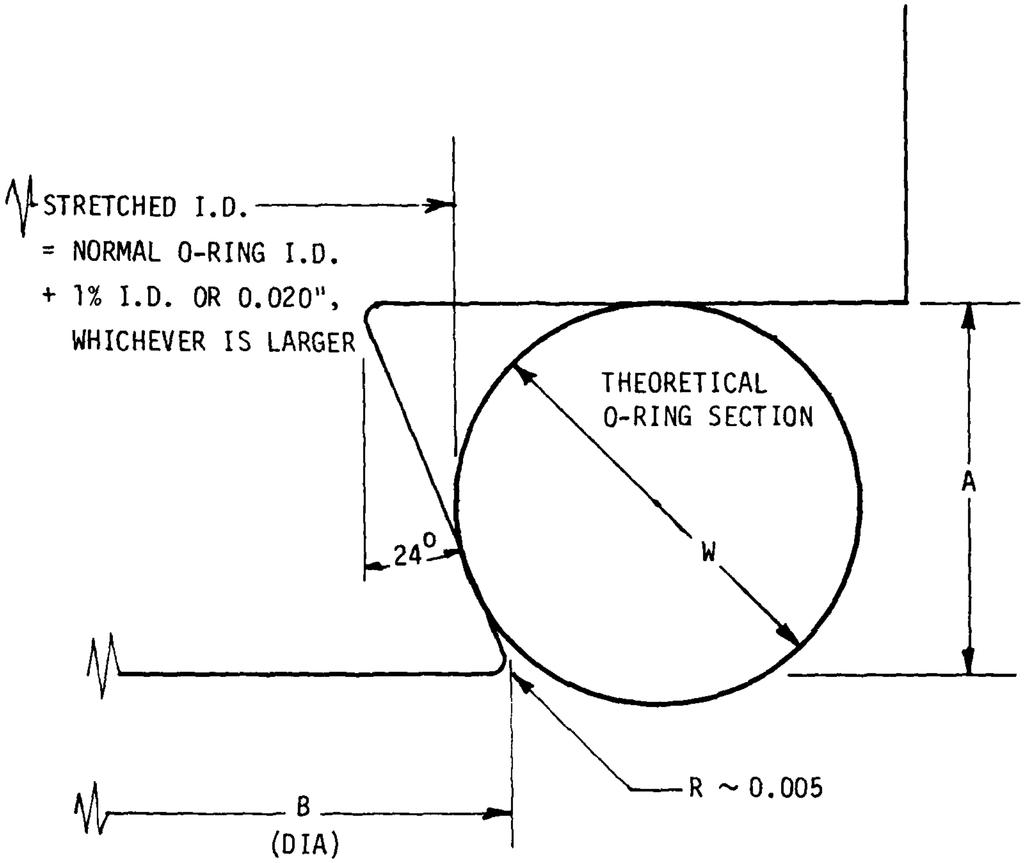
This combination of materials (nickel aluminum bronze and 316 stainless steel) has also performed well from a galvanic and crevice corrosion standpoint for the past twenty years.

The connector should be designed to withstand at least 100 matings and not show wear which would be detrimental to the connector's operation, electrical or mechanically.

6.3.9 Seal - Plug to Receptacle - Water leakage paths at the plug and receptacle interface should be sealed with two automatic squeeze-type gasket O-rings. This type of seal has proved most adequate in past years. Redundant flange and radial gaskets are used as a safety measure should one gasket be inadvertently omitted or damaged by installing personnel. This metal-to-metal flange O-ring seal has proved to be one of the least troublesome design elements in the underwater connector developments of the past twenty years. Standard O-ring compounds of BUNA N satisfy the environment very well and have proven adequate over a ten-year span. Figure 6-6 depicts recommended O-ring dovetail groove dimensions for plug-to-receptacle primary seals. The standard 70 durometer Shore A hardness O-rings are recommended for use wherever possible as they are more easily obtained from stock. They can be used at high pressures in face gasket (metal-to-metal) designs. Ninety durometer O-rings can be considered in radial seal designs at pressures in excess of 3000 psi if back-up rings are not used. However, the disadvantages of using 90 durometer O-rings are lack of availability and the possible need to alter the O-ring groove depth to suit the reduced compression requirements.

The connector assembly, when mated to a cable, should be capable of withstanding 2000 hydrostatic pressure cycles at the specified operating depth.

O-ring and other sealing surfaces should be designed, (type and location) for best seal reliability, prevention of seal surface damage by handling, and easy mating of connections.



Nominal O-Ring Section	Actual O-Ring Section, W	A ± .002	B (DIA)
3/32	0.103 ± .003	0.075	Stretched I.D. + .004
1/8	0.139 ± .004	0.110	Stretched I.D. + .014
3/16	0.210 ± .005	0.180	Stretched I.D. + .043
1/4	0.275 ± .006	0.250	Stretched I.D. + .066

FIGURE 6-6 RECOMMENDED DOVETAIL O-RING GROOVE DIMENSIONS

6.3.10 Insulation and Seal - Pin Contact - Pin contacts which are normally part of the fixed receptacle in underwater applications, are generally sealed in ceramics, elastomers, glass, and plastics. The insulation serves both as a dielectric and a seal to resist the forces of hydrostatic pressure which may be transmitted through the plug and cable assembly. More important, should the cable or plug become damaged, the conductor seal must prevent the full water pressure from penetrating further into the system (component or pressure hull). Glass, ceramic and silicoceramic pin insulations should be used for high pressure applications.

With underwater electrical connector designs, of primary concern is sealing and insulating the electrical contacts within the receptacle. This applies particularly to the hermetic seals. A conductive path must be provided through the pin contacts without existence of electrical leakage paths through or across the surface of the insulating material. Connectors must be electrically sound when delivered by the connector manufacturer, they must stand the stresses of storage, installation within components, shipboard installation at the shipyard, and during their life, be maintainable. The USN has found in the past twenty years that compression glass sealing contacts is one of the most effective sealing methods available for deep submergence connectors.

Glass sealing has been classified as a Grade A seal in accordance with MIL-S-8484 (USAF) Reference 6-12. A Grade A seal is defined as, one which is accomplished by fusion of metal with ceramic materials, including also the fusion of metals by welding, brazing or soldering; the fusion of ceramic materials using heat or pressure, and the fusion of ceramic materials into a metallic support. The use of compression seals between metal and glass falls within the Grade A classification. Under the development mentioned above, the use of compression glass sealing techniques has resulted in the issuance of three underwater connector military specifications (MIL-C-22539, MIL-C-22249 and MIL-C-24217).

Epoxy sealed and insulated pin contacts have been widely used in connector receptacle designs for tactical submarine applications. MIL-C-24231 connectors are a good example of these designs. The contacts are molded into a receptacle insert assembly which is sealed to the receptacle body with an O-ring gasket. These have proven effective over the past twenty years.

6.3.11 <u>Insulation and Seal - Socket Contact</u> - The socket contact insulation and seal is normally located in the plug. The insulator should seal the contact to the plug body and provide proper electrical insulation. Also, the insulation should provide rigid support for the contacts to withstand the high hydrostatic forces. Candidate materials for this component include glasses, ceramics, plastics and elastomers. To protect the cable harness, it is desirable to seal the socket contacts and insulator to the plug to prevent water flow into the plug internals should the plug be inadvertently disconnected in water. With this protection and proper cleaning, the harness assembly can be used again.

MIL-C-24231 plug designs use polyurethane rubber (MIL-M-24041) to seal and insulate the socket contacts. Glass filled diallyl phthalate per GDI-30F of MIL-M-14 is used to insulate the socket contacts in MIL-C-24217 plug connectors. Glass filled epoxy materials are employed in many commercial underwater connector designs.

The selection of insulating materials for electrical connectors should be based on a comparison of the electrical, mechanical, thermal and chemical requirements of a particular application with the properties of candidate materials.

In this selection process, fabrication characteristics, include tooling, required tolerances, production rate, and material cost must also be considered.

Electrical properties important in a particular insulator application include:

(a) Dielectric strength
(b) Insulation resistance
(c) Dielectric constant

Mechanical properties include:

(a) Tensile strength and ultimate elongation
(b) Flexural strength and modulus
(c) Compressive strength
(d) Shear strength
(e) Impact strength
(f) Hardness
(g) Dimensional stability/linear shrinkage

Thermal properties that are important include:

(a) Coefficient of thermal expansion, relative to dimensional stability
(b) Heat aging resistance - affecting dimensional stability and other properties
(c) Short term temperature resistance
(d) Heat deflection temperature
(e) Thermal shock resistance
(f) Flammability

Chemical properties of importance include:

(a) Water vapor permeability
(b) Resistance to cleaning solvents

All insulating materials have specific desirable characteristics and other properties that are less than optimum. The selection of an insulating material represents a compromise or balancing of desired properties with property limitations.

Dielectric strength is the material property of greatest concern in considering insulating materials. This electrical breakdown occurs when the applied electrical stress exceeds the dielectric strength of the insulating material.

This property is evaluated by a *dielectric withstanding voltage* test. A specimen is subjected to an AC voltage increased at a controlled rate. The major variables affecting the dielectric strength of a material are: thickness, area, time, temperature, humidity, frequency (Reference 6-13).

The desired physical properties of insulators as noted earlier are straightforward. In past years, the compressive strength, impact strength and dimensional stability of the socket contact insulators have been of great importance. The design of the MIL-C-24217 connector required insulator materials with these properties because the plastic acts as a load bearing member when the plug is subjected to hydrostatic pressure. Materials such as delrin, polycarbonate, epoxy, melamine, and diallyl phthalate were evaluated. Glass-filled diallyl phthalate was the only candidate material which fully met the physical requirements.

6.3.12 Seal - Cable to Plug - The major design consideration in this seal is to provide a watertight joint between a rigid material (the plug) and an elastomeric material (the cable). See Figure 6-7. A hermetically sealed connector is useless if water leaks between the cable and plug.

The automatic squeeze gaskets, such as the O-ring and Quad ring, are used universally to seal spaces between two rigid surfaces. These gaskets have also been used with some success for sealing the relatively rigid coaxial cables to metal, but are not at all practical with flexible electrical cables. The seal concept is based initially on sealing the gasket material at installation; hydrostatic pressure then helps to increase the effectiveness of the seal. However, the relative compressibility of the cable prohibits the use of automatic squeeze gaskets. The initial pressure on the gasket is soon lost by creep or cold flow of the cable jacket and insulation material. When the initial seal is lost, a seal between the two materials is not possible at low pressures (approximately 0-30 psig). The automatic squeeze gasket, then, has limited use here.

The automatic lip gasket is the second considered. A cylindrical rubber boot is compression molded to the cable jacket, then the boot is interference fitted to a metal shell to form an initial pressure seal. The external hydrostatic pressures only increase the seal effectiveness. This design has been used by several manufacturers for underwater connections but this seal is not considered to be the best. Because the rubber is tensioned over a metal sleeve, it can relax over a period of time and lose the initial seal. In view of this possibility, a more effective, reliable and permanent seal is necessary.

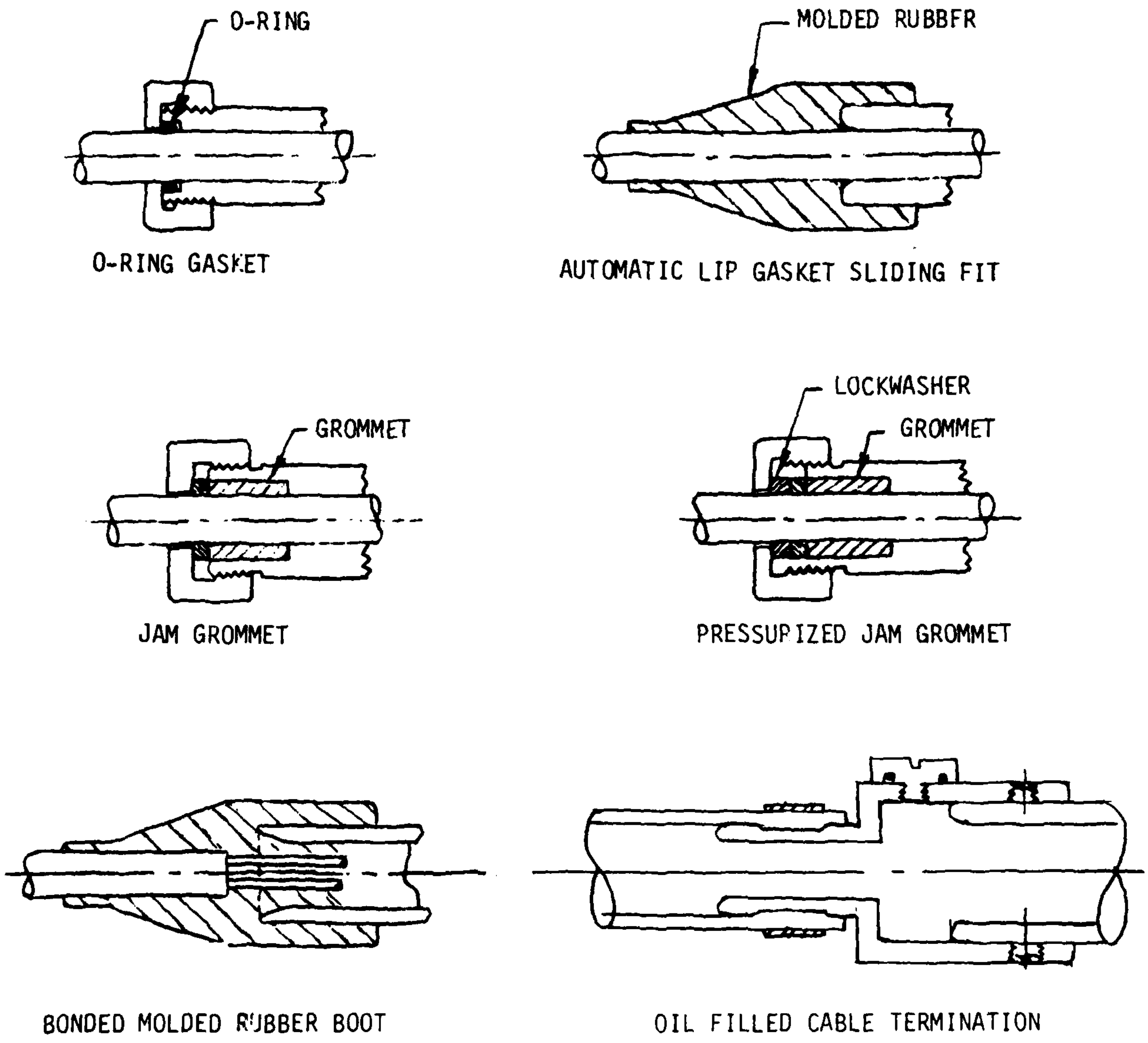


FIGURE 6-7 CABLE-TO-PLUG SEAL TYPES

The jam grommets are made by slipping a rubber grommet over a cable, placing the cable and grommet in a stuffing tube, and pressurizing the grommet in a gland nut. The floating gasket has a spring (lockwasher) to assure constant pressure on the grommet (packing). The jam seal is not seriously considered since it has been superseded by the floating packing seal for flexible cable applications. The jam seal requires careful intermittent grommet pressurization to maintain a seal due to cold flow of the cable jacket and grommet material relaxing over extended periods. Care is required to prevent excessive cable compression and deformation.

The pressurized jam grommet is an outgrowth of the jam seal. A spring is placed in the stuffing gland for constant pressure on the packing over extended periods despite cable material cold flow. The design has found wide acceptance for sealing submarine cables since World War II; however, the seal is not entirely reliable. Submarines have experienced seal failures. In view of this fact, and more stringent high hydrostatic pressure design requirements, this seal is unsuitable for outboard submarine application and was not further pursued.

Past experience has shown that the bonded molded rubber boot seal can best be accomplished with the use of an elastomeric material such as polyurethane or neoprene properly bonded tc the cable and plug body. The selection of the best elastomeric material to suit the application, giving consideration to resistance to the sea water environment, bondability to cable jackets and plug materials, and molding methods which best suit the application is most important. The material and adhesive finally selected must include the following property considerations:

- (a) Strength and toughness
- (b) Elasticity and resilience
- (c) Bonding potential
- (d) Environmental stability
- (e) Insulation resistance
- (f) Application methods
- (g) Water permeability

(h) Material plastic flow
(i) Fatigue life
(j) Compression set
(k) Water absorption

Oil filled cable termination to a connector is another method used to seal a "cable jacket" to a connector. As seen in figure 6-7, an adapter is O-ring sealed and fastened with screws to the plug sleeve. An O-ring sealed screw is provided in the adapter for cable oil filling and venting. The adapter is necked down to receive the tubing which is usually press fitted over the adapter and held in place with one or two cable clamp devices.

Finally, an interference cable-to-housing seal has been designed by Professor J.B. Morrison of the applied Physics Laboratory of the University of Washington. See references 6-14 and 6-15. The action of the interference cable seal is automatic. When the cable is passed through the packing no additional compression adjustments are necessary. See Figure 6-8. The initial pressure is created by passing the cable through a packing or interference fit. This initial pressure remains in constant excess of whatever additional hydrostatic pressure is generated through increased ocean depth. The sealing action is due to the properties of the pliable solid rubber compounds which are readily deformed but are practically incompressible. The seal requires no tightening or special preparation for immersion other than that provided by the fit of the packing with its housing and the fit of the cable with the packing. Reference 6-4 provides additional information on this type of cable seal. This type of cable seal is reported to have been used successfully since the mid 1940's on bottom mounted sonar arrays, submarines and surface ships. Figure 6-9 shows a typical use of the Morrison cable seal on a repeater housing assembly. The basic seal arrangement is made up of an upper and lower seal and washer assembly, separated by a cup which contains a Cerrobend potting alloy. The seals have an interference fit with the cable and housing, and their backup washers have a clearance fit.

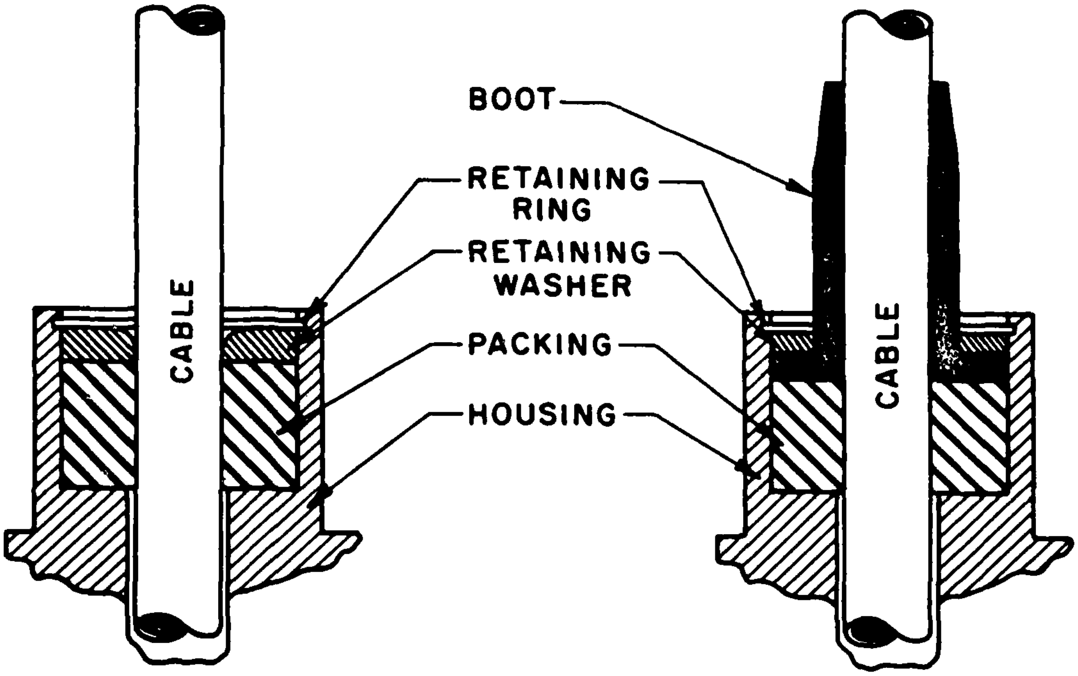
The recommended cable-to-plug seal designs are discussed in further detail in Section 9.7.1 of this Handbook. Specific material selection is discussed in that section.

6.3.13 Cable Strain Relief - Cable strain relief is often the least considered design element in the development of a cable seal assembly. This feature should be incorporated, however, in any cable seal to provide a gripping area to prevent the cable from exerting an axial force on the cable seal when subjected to hydrostatic pressures. For instance, where slip-on-grommet cable seal packings are used a cable strain relief clamp should be provided on the front face of the gland nut. The grommet should seal the cables but should not be required to prevent cable movement.

The strain relief should also prevent an axial force from being applied to the individual conductors in handling the plug-cable harness. The most common cable strain relief methods are as follows:

(a) Clamping (the best examples of which are the cable clamps used with connector backshell type plugs).
(b) A pressurized grommet that is also a moisture seal.
(c) Molded rubber boots, and
(d) Kellems Company cable grip (see Figure 6-10).

Most pressure-proof connector designs make use of a tapered molded rubber boot to provide cable strain relief as the cable exits the plug shell. The molded rubber boot is considered adequate for most sonar system applications.



(a) W/O Boot

(b) With Boot

FIGURE 6-8 MORRISON CABLE-TO-HOUSING INTERFERENCE SEAL

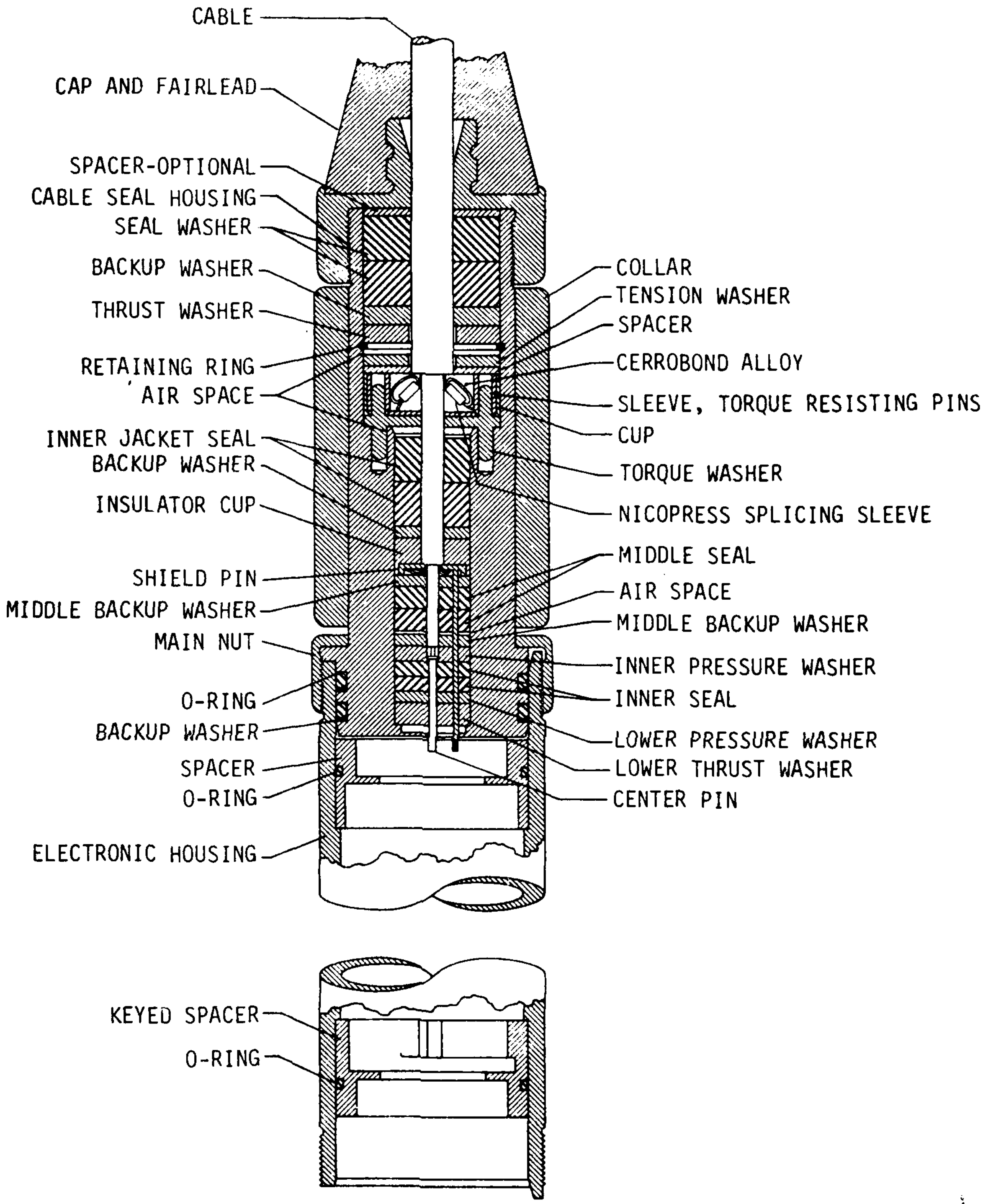
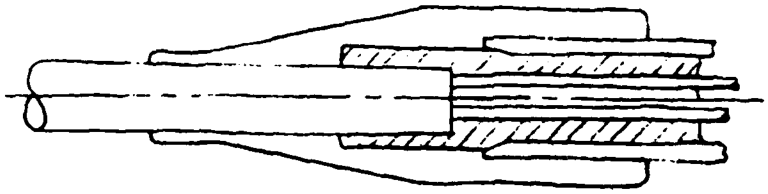
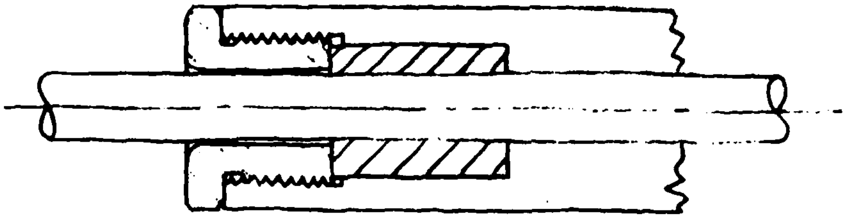


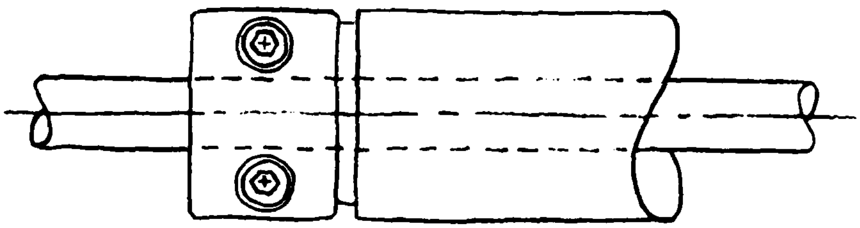
FIGURE 6-9 MORRISON INTERFERENCE CABLE SEAL AND REPEATER HOUSING ASSEMBLY



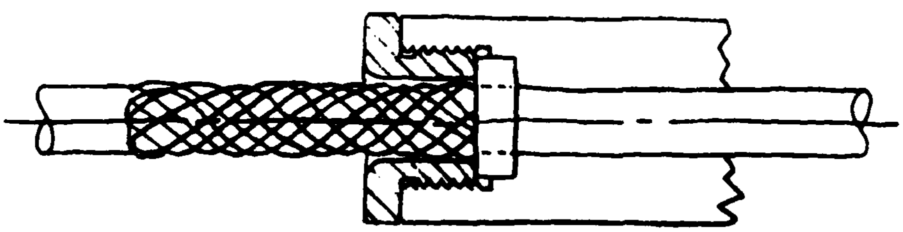
MOLDED RUBBER BOOT



PRESSURIZED GROMMET



CABLE CLAMP



KELLEMS COMPANY'S CABLE GRIP

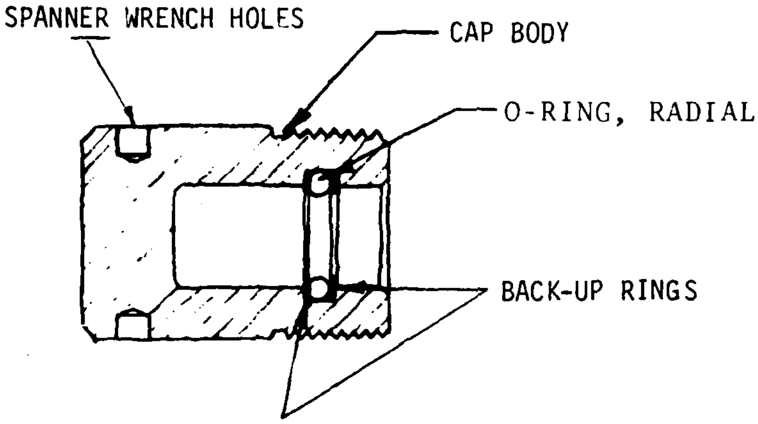
FIGURE 6-10 CABLE STRAIN RELIEF METHODS

6.3.14 Connector Accessories

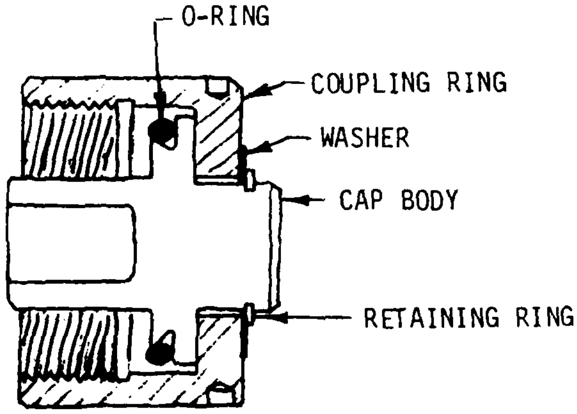
6.3.14.1 *Pressure-Proof Covers* - Pressure-proof plug and receptacle covers (or caps) are necesary accessories for connectors. The covers provide a watertight envelope at the mating faces of the plugs and receptacles when they are not normally mated to their counterpart connectors whether in service or during test programs. The pressure-proof covers should be designed to withstand one and one-half times the operating depth pressures of the connector. The basic design of these components is straightforward as seen in Figure 6-11.

The MIL-C-24217 plug cover is essentially a one piece body which houses a radial O-ring gasket. Spanner wrench pin holes are drilled into the body to facilitate coupling. The receptacle cover is basically a two-piece assembly. The body is similar to the plug shell without the socket contacts. The standard plug coupling ring is used to make the cover to the receptacle. The receptacle shell houses the O-ring gasket in a dovetail groove.

6.3.14.2 *Protective Covers* - Each fabricated plug and receptacle should be fitted with protective covers on the front and rear faces.. These covers protect the mating and sealing surfaces as well as the contacts located within the plug and receptacle shell. These protective caps also keep foreign matter from entering the cavities of the plug and receptacles. The protective covers (caps) can be fabricated from any reasonably high impact plastic such as polycarbonate, nylon, ABS, and delrin along others; or from a metallic material such as aluminum. Covers of this type are absolutely essential to assure the quality of the connectors throughout the manufacturing, test, shipping, and installation cycle.



PRESSURE PROOF PLUG CAP



PRESSURE PROOF RECEPTACLE CAP

FIGURE 6-11 PRESSURE PROOF CONNECTOR COVERS

6.3.15 Electrical Requirements

Insulation resistance and dielectric withstanding voltage are the major electrical concerns in connector design for sonar systems. A minimum insulation resistance requirement of 2000 megohms is not unreasonable to expect from connector products as received from vendors. Vendor withstanding voltage tests should be conducted at twice the operating voltage plus 1000 volts. It should be remembered that this is a destructive test and should not be conducted indiscriminately by users. Coaxial type connectors are required in a small number of applications. Here, voltage standing wave ratio and insertion loss tests are conducted to verify adequacy of connector design.

REFERENCES

6-1 "Handbook of Vehicle Electrical Penetrators, Connectors and Harnesses for Deep Ocean Applications" Section 5, Deep Ocean Technology Program, Naval Ship Engineering Center, Hyattsville, Md., AD 888-281, July 1971

6-2 DSSP Instruction 9020.2, Guidelines for Corrosion Control, PMS-11/201/SH: PM of December 31, 1968.

6-3 Jerome, R. and J.L. March, Designers Guidelines for Selection and Use of Metallic Materials in Sea Water Applications, Electric Boat division Report of December 8, 1966.

6-4 Tuthill, A.H. and C.M. Schillmoller, Guidelines for Selection of Marine Materials, International Nickel Co., 1966.

6-5 Myers, J.J. Handbook of Ocean and Underwater Engineering, McGraw Hill Book Co., New York, (Section 7, "Corrosion" B.F. Brown, and "Materials for Marine Use." R.C. DeHart.) 1969.

6-6 Uhlig, H.H. Corrosion Handbook, John Wiley and Sons, Inc., New York, 1948.

6-7 LaQue, F.L. and H.H. Capson, Corrosion Resistance of Metals and Alloys, Reinhold Publishing Corp., New York, 1963.

6-8 Brown, B.F. Corrosion in the Marine Environment, MTS 6th Annual Conference, pp. 1225-1231, June 24 - July 1, 1970.

6-9 Tuthill, A.H. and C.M. Schillmuller, Guidelines for Selection of Marine Materials, The International Nickel Co., New York, 1966.

REFERENCES (cont'd.)

6-10 "Corrosion and Corrosion Protection of Metals" MIL-HDBK-721(MR) Military Standardization Handbook, November 1, 1965.

6-11 Materials Engineering/Materials Selector '81, December 1980. Penton/IPC subsidiary of Pittway Corp., 1111 Chester Ave., Cleveland, OH 44114.

6-12 MIL-S-8484, "Seals, and Seal Testing Procedures (for electronic enclosures)."

6-13 Craig, C.L., "Electrical Properties of Plastics - What They Mean to the Designer", Plastics Design and Processing, February 1962.

6-14 Reference Manual on Interference Seals and Connectors for Undersea Electrical Applications, prepared by the Applied Physics Laboratory of the University of Washington for the Naval Facilities Engineering Command, Chesapeake Division (available from NTIS, 5285 Port Royal Rd., Springfield, VA 22161; ref. Publ. AD-A036841), June 1976.

6-15 Sandwith, C.J., Paradis, J.G., and Morrison, J.B., "Underwater Electrical Cable and Connector Seals; Some In-House Design Options, Commercial Options, and Performance/Failure Analysis", MTS-IEEE Ocean 1977 Conference Record, Vol. 2, pp 29C-1 thru 29C-6, October 17-19, 1977.

(Blank)

SECTION 7

PRESSURE-PROOF CONNECTOR RECEPTACLE ATTACHMENT METHODS

LIST OF FIGURES

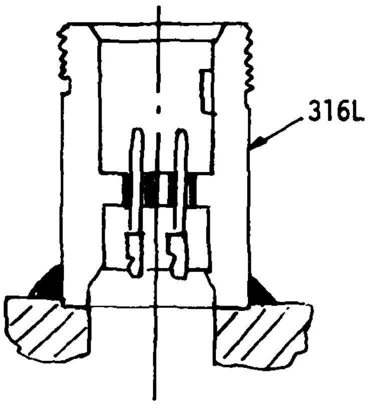
LIST OF TABLES

7.1 Introduction

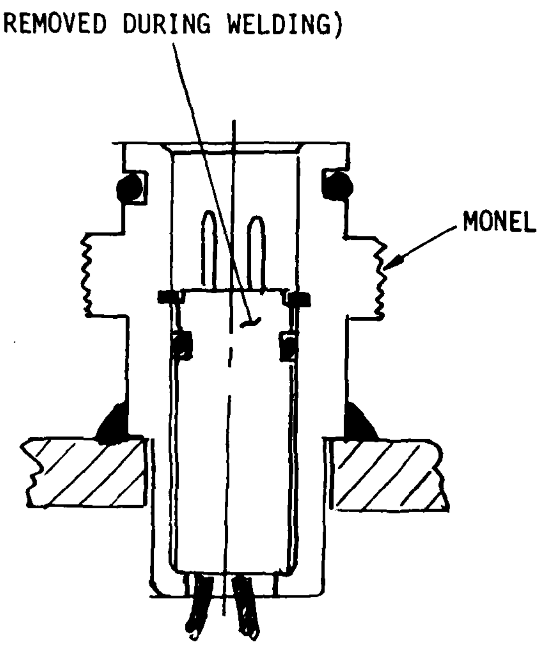
Pressure-proof receptacles are attached to other components by welding, threading, bolting, or elastomeric bonding. This section describes these methods and their applicability to the various receptacle styles.

7.2 Welded Receptacles

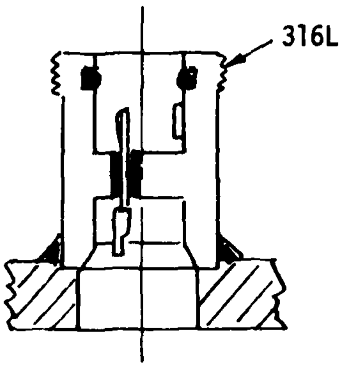
Figure 7-1 depicts the four most commonly welded receptacles, MIL-C-22539, MIL-C-24217/1 and 2, and MIL-C-24231/12, 13 and 14. Recommended procedures for their welding to a variety of component materials are given below, including precautions for the prevention of distortion or seal damage. Welded receptacles are preferred in applications where the equipment must withstand exposure to underwater explosion.



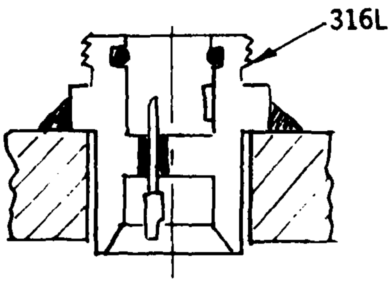
MIL-C-22539



MIL-C-24231/12, 13 and 14



MIL-C-24217/1
WELDED STYLE



MIL-C-24217/2
FLANGE WELDED STYLE

FIGURE 7-1 WELDED RECEPTACLES

7.2.1 Welding Procedures - General Requirements

7.2.1.1 The methods, procedures and specifications listed below and in Table 7-1 are recommended for welding pressure-proof electrical receptacle assemblies to other components. Welding and inspection shall be in accordance with MIL-STD-278, NAVSHIPS 250-1500-1, NAVSHIPS 0900-000-1000, or NAVSHIPS 0900-006-9010, as applicable. Joint design should be similar to PT2S.1 of MIL-STD-22 for non-nuclear applications, or TN-16 of NAVSHIPS 250-1500-1 for nuclear applications.

7.2.1.2 Operator qualifications shall be in accordance with MIL-STD-248 or NAVSHIPS 250-1500-1, as applicable.

7.2.1.3 Preheat temperature, interpass temperature, and electrode or filler material shall be as specified in Table 7-1. Interpass temperature is defined as the temperature of the material to be welded in the area of the next weld pass, prior to beginning that pass. Water or wet rags shall not be used to reduce interpass temperature. Forced air cooling is permissible.

CAUTION

EXCESSIVE HEAT OR THERMAL SHOCK CAN DAMAGE THE GLASS SEALS AROUND CONTACTS OF MIL-C-22539 OR MIL-C-24217 TYPE RECEPTACLES. STRICT COMPLIANCE WITH THE SPECIFIED WELDING PROCEDURE IS THEREFORE ESSENTIAL. MAXIMUM TEMPERATURE OF THE RECEPTACLE BULKHEAD CONTAINING GLASS SEALS SHALL NOT EXCEED 300°F AS MEASURED BY TEMPILSTIK OR OTHER INDICATING MEANS.

7.2.1.4 Temperature indicators shall be located at 90° intervals on the outside wall of all receptacles and components, approximately 0.750 inches from the weld area, and at 90° intervals on the bulkhead of glass sealed receptacles, 0.125 inch from the outermost glass bead.

7.2.1.5 The area of the component and receptacle to be welded shall free of oil, grease, or other foreign matter. Oil and grease shall be removed by 1,1,1 - trichloroethane or similar cleaning agent.

7.2.1.6 Metallic protective covers shall be in place on receptacles throughout all welding operations to exclude foreign material. O-rings and non-metallic inserts shall be removed before welding, and stored in a clean polyethylene bag.

7.2.2 Welding Procedures - Receptacles

(1) Table 7-1 and the following procedures define the attachment of receptacles by welding.

(2) Locate the receptacle in the hole or spotface of the component with the polarizing key in the position indicated by the specific assembly drawing.

(3) Tack weld the receptacle to the component in four places prior to starting the first root pass segment.

(4) Deposit the root pass bead in segments, and in the amount and sequence shown in Figure 7-2. Experience indicates that not more than two segments of any one bead can be added before interpass temperature limits are exceeded. At this point, welding must stop on this receptacle until the parts have cooled below the specified temperature. However, when welding multiple receptacle hull fittings, welding may proceed immediately on another receptacle located on the opposite side of the fitting.

(5) After completion of the pass, grind the bead, where necessary, burring all areas showing evidence of porosity, entrapped slag, or lack of fusion.

(6) Examine the weld for porosity by the liquid penetrant method in accordance with MIL-STD-271, NAVSHIPS 250-1500-1, or NAVSHIPS 0900-003-8000, as applicable.

(7) Proceed with the second and third passes following the procedure of 7.2.2.4 locating the beads as shown in Figure 7-3 and in the amount and sequence shown in Figure 7-2.

(8) Repeat 7.2.2.5 and 7.2.2.6.

7.2.3 Welding Procedure - Stainless Steel Buttering of HY-80 Components

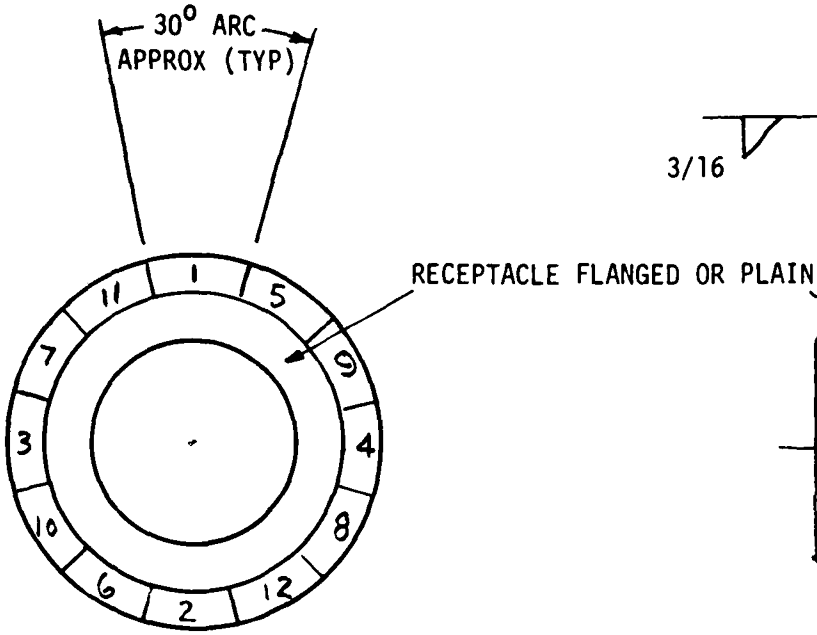
(1) Table 7-1 and the following procedures define the preparation for receptacle welding of HY-80 components by 'buttering' with stainless steel, when required by the assembly drawing.

(2) Stringer beads shall be deposited in the sequence shown in Figure 7-4. Bead widths shall not exceed 3 electrode core wire diameters. Quantity of beads will vary depending on joint size and welder's technique.

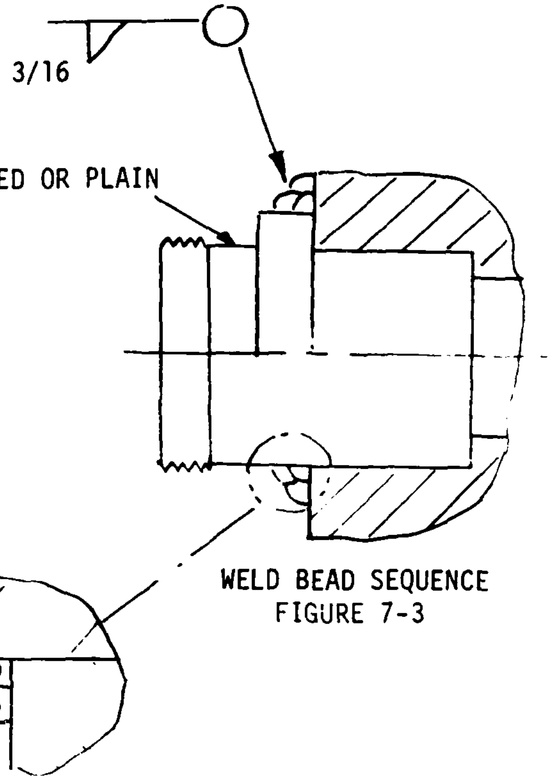
(3) The depth of buttering shall be sufficient to present a uniformly smooth surface free of rejectable surface defects with a buttering thickness not less than 3/16 inch after machining.

(4) Beads should be burred where there is visual evidence of porosity, slag entrapment, or lack of fusion prior to depositing the next bead, and prior to non-destructive testing.

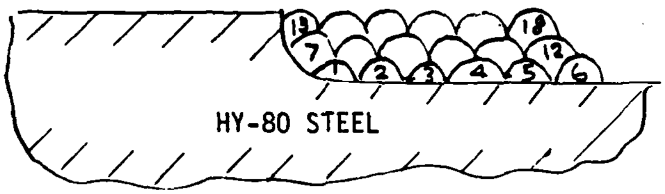
(5) Upon completion of the finish layer, a visual and a liquid penetrant inspection per MIL-STD-271, NAVSHIPS 250-1500-1, or NAVSHIPS 0900-003-8000, as applicable, shall be made.



WELD SEGMENT SEQUENCE
FIGURE 7-2



WELD BEAD SEQUENCE
FIGURE 7-3



TYPICAL BEAD DEPOSITION SEQUENCE FOR STAINLESS STEEL BUTTERING

FIGURE 7-4 WELDING SEQUENCE FOR PRESSURE-PROOF RECEPTACLES

TABLE 7-1

WELDING PARAMETERS FOR PRESSURE-PROOF RECEPTACLES

Joint Description	Welding Methods	Preheat Temp. °F, Min.	Interpass Temp. °F, Max.	Filler Wire Spec.	Electrode Specification	Electrode Diameter	Welding Amps	Current Polarity
Stainless steel buttering on HY-80 steel	Shielded Metal Arc (SMAW)	125	300	-	MIL-E-22200/2 Type MIL-309-15, MIL-309CB-15 or MIL-310-15	3/32 1/8 5/32	69-90 90-130 130-155	Reverse " "
316L receptacle/ stainless steel buttered HY-80 steel component	Shielded Metal Arc (SMAW)	60	300	-	MIL-E-22200/2 Type MIL-316L	3/32 1/8	35-90 50-120	Reverse "
"	Gas Tungsten Arc (GTAW)	60	300	MIL-E-19933 Type MIL-316L	2% Thoriated Tungsten	1/16	80-125	Straight
316L receptacle/ 316L component	Shielded Metal Arc (SMAW)	60	300	-	MIL-E-22200/2 Type MIL-316L	3/32 1/8	35-90 50-120	Reverse "
"	Gas Tungsten Arc (GTAW)	60	300	MIL-E-19933 Type MIL-316L	2% Thoriated Tungsten	1/16	80-125	Straight
316L receptacle/ Monel component	Shielded Metal Arc (SMAW)	60	200	-	MIL-E-22200/3 Type MIL-8N12	3/32 1/8	60-80 80-115	Reverse "
"	Gas Tungsten Arc (GTAW)	60	200	MIL-E-21562 Ty-MIL-EN82 or MIL-RN82	2% Thoriated Tungsten	1/16	60-90	Straight
Monel receptacle/ Monel or K-Monel component	Shielded Metal Arc (SMAW)	60	200	-	MIL-E-22200/3 Type MIL-9N10	3/32 1/8	50-80 70-135	Reverse "
"	Gas Tungsten Arc (GTAW)	60	200	MIL-E-21562 Ty-MIL-EN60 or MIL-RN60	2% Thoriated Tungsten	1/16 3/32	70-150 90-140	Straight "

NOTE: ELECTRODE DIAMETER, CURRENT POLARITY, AND AMPERAGE ARE RECOMMENDED APPROXIMATE VALUES ONLY, AND ARE SUBJECT TO MANUFACTURER'S WELD PROCEDURE QUALIFICATION.

7.2.4 Other Welding Processes and Materials

Only the more commonly used receptacle materials and welding procedures have been described thus far. Other materials and processes, such as the examples below, may be used provided that qualifications are first performed as required by MIL-STD-248 or NAVSHIPS 250-1500-1.

7.2.4.1 *Welding Titanium Receptacles* -

Titanium alloy (Ti-6AL-4V) can be welded with a high degree of reliability and the welds have the same high degree of corrosion resistance as the base metal in a sea water environment. Fusion welding either by the GTAW (Gas Tungsten Arc) or GMAW (Gas Metal Arc) process can be accomplished with or without filler wire. The more important factors in welding Ti-6AL-4V are joint preparation, fit-up, and careful shielding of the weld and heated zones to preclude pick-up of contaminants from the air by the molten or hot titanium. Shielding may be accomplished by flooding the area immediate to the weld both top and bottom of the joint, with an inert gas or by welding in a chamber filled with an inert gas and purged of the common contaminants, oxygen, hydrogen, nitrogen, and carbon. Both metal and filler wire must be thoroughly cleaned. Metal degreasing should be accomplished with alcohol or acetone. Never use steel wool or sand paper for dirt removal. A clean stainless steel brush should be used for this purpose. The filler wire should be cleaned and the end removed just prior to use. Wire feed should be continuous, not dabbed.

Resistance welding of Ti-6AL-4V is also possible and techniques are much the same as would be used for stainless steel. Inert gas protection is not necessary due to the proximity of the mating surfaces. Electron beam welding can also be used with this alloy.

7.2.4.1 (Continued)

Fusion welding by the GTAW method is recommended for use on glass sealed contact connectors. The method permits intense localized heat without excessive heat build-up in the area of the glass seal which could be damaging to the glass. GTAW produces a superior weld with the temperature restricting conditions imposed by the connector weld procedure.

7.2.4.2 *Electron Beam Welding of Receptacles -*

Electron-beam welding (EBW) may be advantageous where ultra precision and quality are required, or where dissimilar metals must be joined. It is primarily applicable to butt weld joints only, and would therefore not be suitable for the fillet weld joint commonly used for attaching receptacles.

In electron beam welding, a high voltage electron beam is focused to produce a clean, deep weld. No filler material is used. Heating is very localized and the weld produced has a high depth to width ratio, usually 25:1. The process works in all positions.

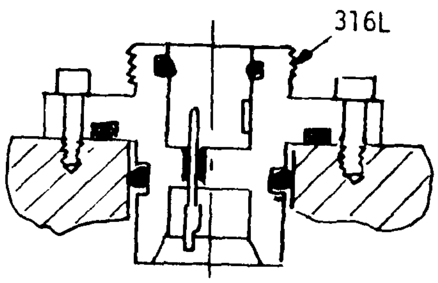
Electron beam equipment is relatively costly, consisting of a high vacuum system, vacuum chambers, beam generating and focusing equipment, work piece holding and traversing mechanisms, and X-ray shielding. In all cases, the beam must be generated in a vacuum, but the work piece may be in full vacuum, partial vacuum, or in air.

Work pieces must be clean and with few inclusions before welding. Precise fit-up of the joint, accurate alignment of the beam, and precise traversing of the work piece are required to avoid undercutting, skipping, or no weld at all. Superior operator skill is important, and 100% non-destructive inspection (ultra-sonic, magnetic particle, or X-ray) is recommended after welding.

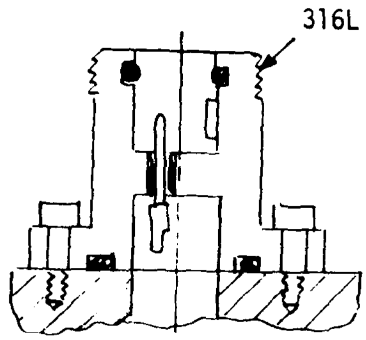
Requirements for electron beam fusion welding are defined in MIL-W-46132.

7.3 Threaded or Bolted Receptacles

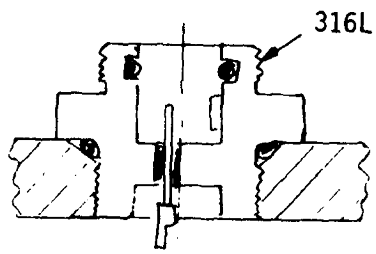
Figure 7-5 illustrates the various MIL-C-24217 receptacles which are attached to components with threaded fasteners. MIL-C-24217/4 and 12 receptacles contain a mounting flange midway along the sleeve with bolt holes and an O-ring seal groove for mounting. MIL-C-24217/5 is identical except for the flange being at the inboard end of the receptacle sleeve. MIL-C-24217/6 is a mid-flange receptacle similar to the bolted version, except that retention is accomplished by a large nut which is threaded onto the inboard end of the receptacle sleeve. Threaded or bolted receptacles have the advantage of easier maintainability due to ease of replacement.



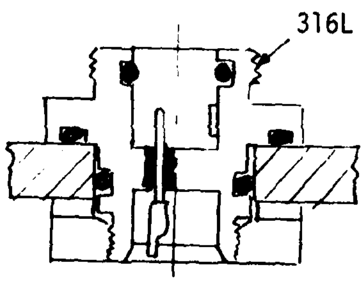
MIL-C-24217/4 OR/12 MID-FLANGED BOLTED STYLE



MIL-C-24217/5 END-FLANGED BOLTED STYLE



THREADED STYLE

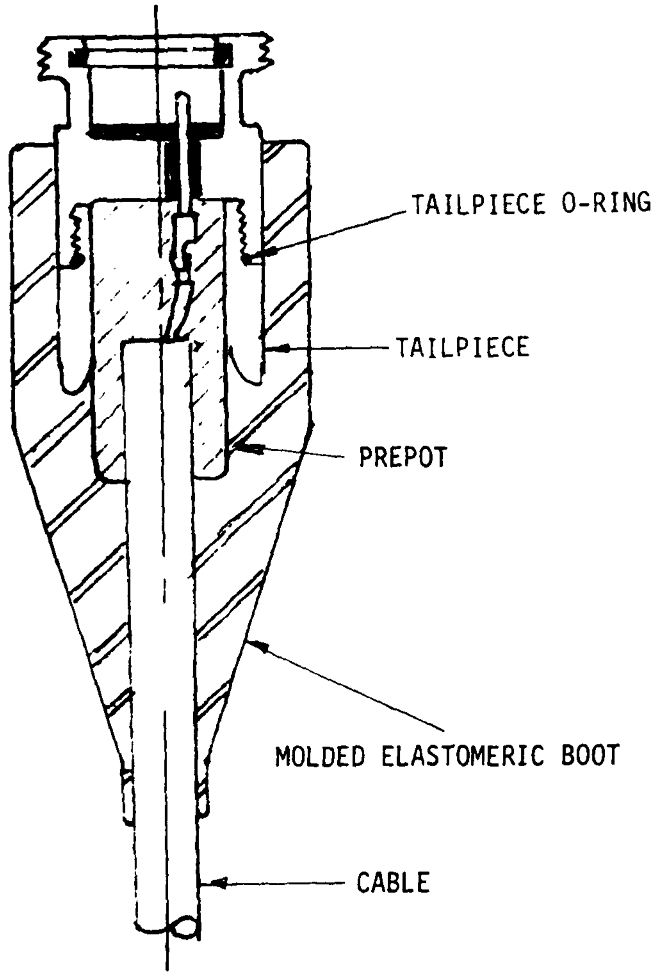


MIL-C-24217/6 OR/13 LOCKNUT FLANGED STYLE

FIGURE 7-5 THREADED OR BOLTED RECEPTACLES

7.4 Elastomeric Bonded (In-Line) Receptacles

The final method of receptacle attachment is found in the MIL-C-24217/3 in-line receptacle shown in Figure 7-6. In this configuration, the receptacle sleeve is molded into an elastomeric boot which joins the receptacle to an elastomeric jacketed cable. The only attachment is therefore the bond between the sleeve and the boot. Procedures for fabrication are the same as for connector plugs in Section 9.



MIL-C-24217/3 IN-LINE RECEPTACLE

FIGURE 7-6 ELASTOMERIC BONDED RECEPTACLE

REFERENCES

7-1 MIL-E-19933 "Electrodes and Rods - Welding, Bare, Chromium and Chromium - Nickel Steels"

7-2 MIL-E-21562 "Electrodes and Rods - Welding, Bare, Nickel Alloy"

7-3 MIL-E-22200/2 "Electrode, Welding, Covered (Austenitic Chromium-Nickel Steel, For Corrosive and High Temperature Services)"

7-4 MIL-E-22200/3 "Electrode, Welding, Covered, Nickel Base Alloy, and Cobalt Base Alloy"

7-5 MIL-C-22539 "Connector Set, Electrical, Hermetically Sealed, Submarine"

7-6 MIL-C-24217 "Connector, Electrical, Deep Submergence, Submarine"

7-7 MIL-C-24231 "Connector, Plugs, Receptacles, Adapters, Hull Inserts, and Hull Insert Plugs, Pressure-Proof, General Specification for"

7-8 MIL-STD-22 "Welded-joint Designs"

7-9 MIL-STD-248 "Welding and Brazing Procedure and Performance Qualification"

7-10 MIL-STD-271 "Non-destructive Testing Requirements for Metals"

7-11 MIL-STD-278 "Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels in Ships of U.S. Navy"

7-12 NAVSHIPS 250-1500-1 "Standard for Welding of Reactor Coolant and Associated Systems and Components for Naval Nuclear Power Plants"

7-13 NAVSHIPS 0900-000-1000 "Fabrication, Welding, and Inspection of Ship Hulls"

REFERENCES
(Continued)

7-14 NAVSHIPS 0900-003-8000 "Surface Inspection Acceptance Standards for Metals"

7-15 NAVSHIPS 0900-006-9010 "Fabrication, Welding and Inspection of HY-80/100 Submarine Hulls"

(Blank)

SECTION 8

OUTBOARD CABLE DESIGN

LIST OF FIGURES

LIST OF TABLES

8.1 Introduction

Outboard submarine cables are designed for service in a seawater environment. The cables are a grouping of insulated conductors in a circular cross section and enclosed by a jacket. The cables normally run from the submarine hull penetrator to the outboard electrical/electronic component. Pressure-proof connectors or cable glands are wired and molded to the ends of the cables to form a cable harness assembly. While most of the cables running outboard on submarines are the rubber jacketed internally water-blocked type, Figure 8-1 shows many designs which have been considered for use in past years. In some cases a number of designs have been used. These include oil filled and mineral insulated cables.

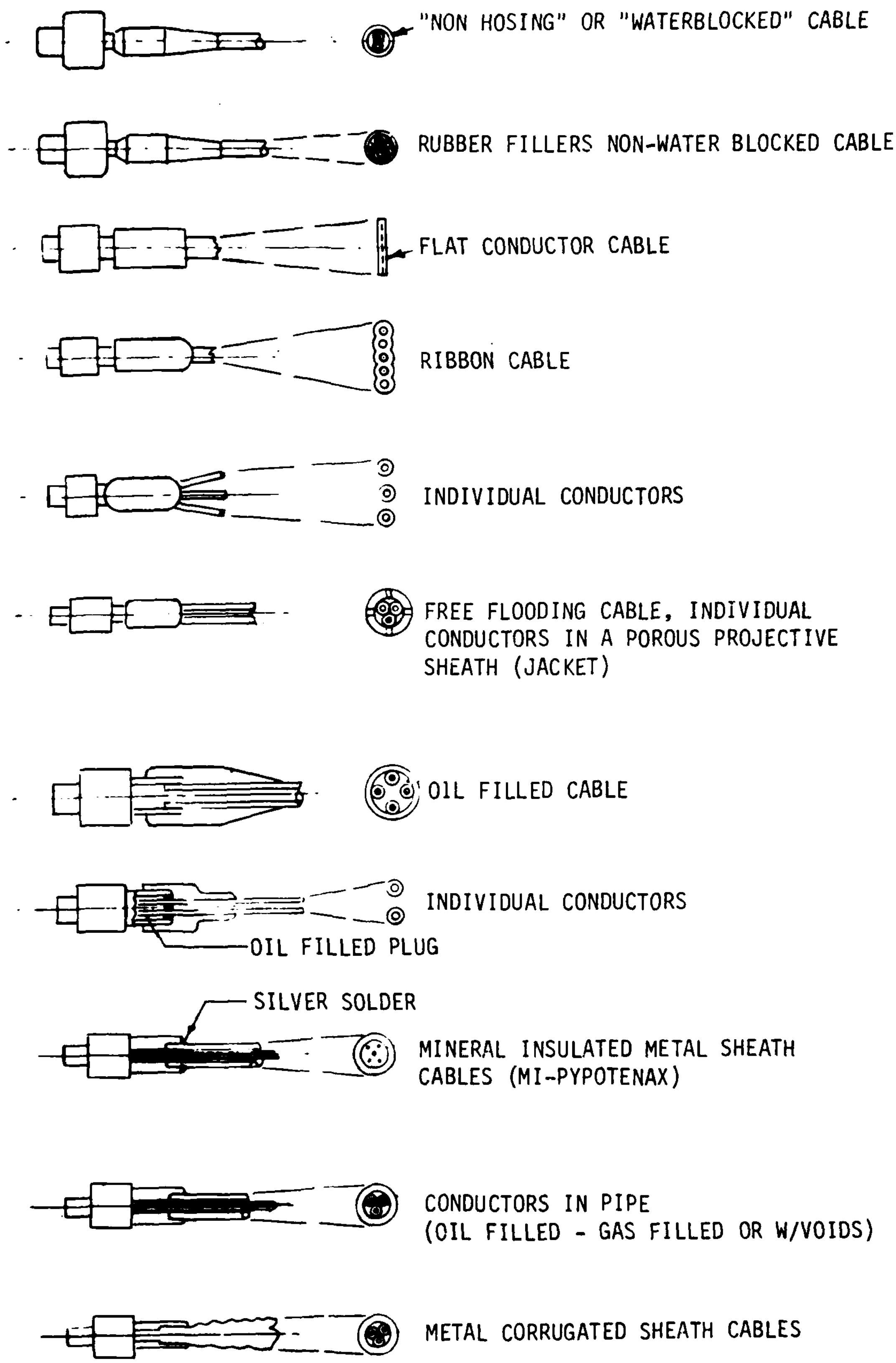


FIGURE 8-1 OUTBOARD CABLE DESIGN TYPES

8.2 Outboard Cable Design Factors

This section covers the design of outboard electrical cables. The design of a cable requires the consideration of many design factors. These are listed in Table 8-1

Table 8-1 Outboard Cable Design Factors

1. Conductors
2. Conductor Stranding
3. Conductor Insulation
4. Conductor Lay Length
5. Shields
6. Shield Insulation
7. Cable Fillers
8. Cable Core Binder
9. Cable Jacket
10. Electrical Requirements
11. Environmental Requirements
12. Physical Requirements
13. Cable Types and Sizes
14. Cable Specifications

8.2.1 Conductors

Copper has been the main electrical conductor material used in Navy applications. However, alloys of copper have also been used in special applications. See Table 8-2. Reference 8-5, "Handbook of Electrical Cable Technology for Deep Ocean Applications", notes that copper makes an excellent choice for conductors due to excellent conductivity, high thermal conductivity, ease of fabrication, reasonable strength, ease of termination, acceptable cost, and ability to be alloyed and coated.

The copper conductor strands are usually coated with a thin layer of tin or silver to protect the copper from sulphur or other chemical compounds present in insulation materials which can corrode the copper. The coating also prevents the build-up of copper oxide at the crimped conductor contact termination and aids soldering the conductors to the connector contacts. Tin is the most commonly used coating. Silver coatings are used in temperature applications above 150°C.

A cadmium chromium copper alloy such s Phelps Dodge Alloy No. PD135 is recommended for conductors of No. 20 AWG size and smaller. Conductors smaller than No. 20 AWG should not be used outboard due to their poorer tensile strength properties. Outboard cables can be subjected to rough handling in the shipyard environment and aboard ship. Therefore, No. 16 AWG conductors and larger, as required for amperage and voltage drop considerations, are recommended for most applications. Copper conductors should conform to ASTM B3, Reference 8-6. Tin coating for the copper conductors should meet the requirements of ASTM B33, Reference 8-7.

TABLE 8-2

CONDUCTOR MATERIAL PROPERTIES

	Specific Gravity	Tensile Strength psi	Elongation %	Resistivity microhm-cm^3	Conductivity %	Applications Requiring	Remarks
Aluminum	2.7	35,000	30-45	2.8264	67	Minimal Weight	Low Modulus, High Coefficient of Expansion, Nick Sensitive
Copper	8.99	35,000	10-35	1.724	100	Normal Service Installations	Excellent General Properties, Economical
Bronze (Phosphorus	8.89	40,000-60,000	3-47	3.6	48	Severe Service, Strength, Flexibility	Rapid Flexing Recovery
Cadmium Copper	8.89	38,000-90,000	1.5-4	2-4	40-85	High Strength and Temperature	
Cadmium Chromium Copper		60,000-110,000	1-8	1.9-2.2	80-90	High Strength, Temperature, Flexibility and Conductivity	Easily Fabricated, Compatible with Fluorocarbon Insulations
Chromium Copper	8.89	41,000-90,000	1.5-2.8	2-3	[illegible]	Flexibility, Strength	
Tellurium Copper	6.25-8.89	40,000+				Strength, Corrosive Resistance, High Temperature	Availability Restricted
Zirconium Copper	9.27	36,000	25	1.9	90	Strength, Flexibility	Noncorrosive
Copper Covered Steel	7.8	100,000-200,000		4.5-5.5	30-40	Strength	

8.2.2 Conductor Stranding

Stranded conductors are used in outboard cable applications for cable flexibility in handling and less susceptibility to conductor kinking at installation. Conductor stranding types are depicted in Figure 8-2. Bunch stranding consists of twisting together of the individual strands in a random arrangement. Bunch stranding provides great flexibility and low cost. Concentric stranding is a geometric arrangement of the individual conductor strands. It consists of helically laid strands with each layer direction reversed. Concentric stranding provides uniform diameters and the strands do not fray or unravel in conductor stripping operations. Unilay stranding has all of the strand layers in the same direction. This type of construction provides greater strand flexibility than concentric stranding. Rope stranding is generally used in large AWG size conductors. This type of stranding provides excellent flexibility because of the small wire sizes generally used. The flexibility of the conductor is also increased by increasing the number of strands and reducing the size of the strands for a given conductor size. It is recommended that concentric lay stranded wire in accordance with ASTM B286, Reference 8-8, be used in fabricating submarine outboard cables. In past years, waterblocked strands have been used by extruding silicone rubber into the interstices of the strands. As internally watertight outboard cables are not required due to the current use of pressure-proof connectors, waterblocked conductor stranding is not recommended.

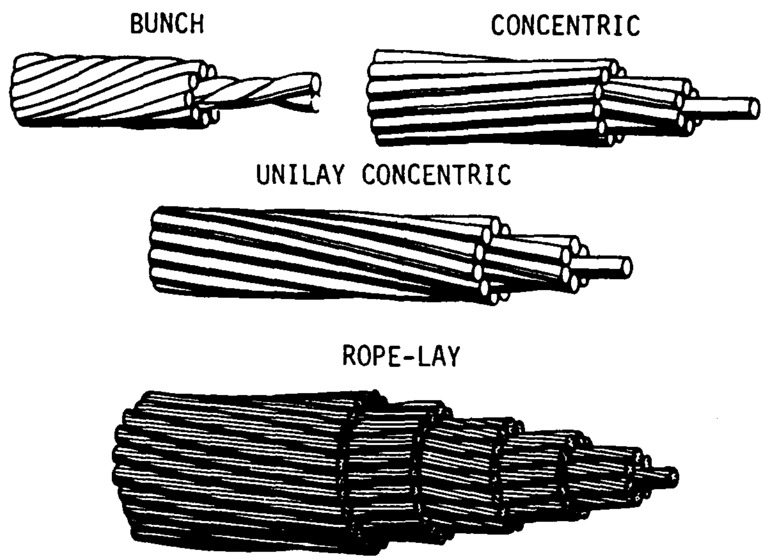


FIGURE 8-2 CONDUCTOR STRANDING TYPES

8.2.3 Conductor Insulation

Conductor insulation for outboard cables must provide mechanical support for the conductors at the connector terminations as well as the necessary electrical insulation. This mechanical support assists in preventing conductor kinking when the cable is subjected to hydrostatic pressure cycling. Many of the relatively new space age plastic insulation materials can be considered for use. See Table 8-2. The use of plastic insulation allows the application of very thin layers (.010 inches when extruded; .006 inches when wrapped). The thin conductor insulation assists in keeping the overall cable diameter to a minimum size and allows for placing the material in the jacket to provide for proper jacket thickness. Materials such as TFE and FEP Teflon and Tefzel are ideal choices for this application. Others are described in Table 8-3. The conductor insulation material should also be capable of withstanding rubber boot molding temperatures at the cable-connector termination. Molding temperatures as high as 300°F are used to mold neoprene rubber boots and 180°F for polyurethane rubber.

Rubber conductor insulation materials are not recommended in this application as the insulation must be applied in relatively thick layers (.030 inch). Also the rubber has been found not to properly support the conductors at the cable-connector termination. Conductor kinking has resulted when the cable assemblies have been subjected to high hydrostatic pressures. It has been necessary to reinforce and insulate the conductors with layers of KYNAR shrink tubing in the termination area. This aspect is also discussed in other sections of the Handbook.

TABLE 8-3

CONDUCTOR INSULATION MATERIALS

Insulation	Common Designation	Tensile Strength (psi)	Elongation (%)	Specific Gravity	Abrasion Resist.	Temp. Resist. (°C)	Cut Through Resistance
Polyvinyl Chloride	PVC	2,400	260	1.2 - 1.5	Poor	-55 +105	Poor
Polyethylene	PE	1,400	300	0.92	Poor	-65 +80	Poor
Polypropylene	--	6,000	25	1.4	Good	-20 +125	Good
Crosslinked Polyethylene	IMP	3,000	120	1.2	Fair	-65 +150	Fair
Polytetra-fluoroethylene	TFE	3,000	150	2.15	Fair	-80 +260	Fair
Fluorinated Ethylene Propylene	FEP	3,000	150	2.15	Poor	-80 +200	Poor
Polyvinyl Fluoride	KYNAR	7,100	300	1.76	Good	-65 +130	Good
Polyamide	Nylon	4,000 - 7,000	300 - 600	1.10	Good	-55 +105	Good
Polyalkene	--	2,000 - 7,000	200 - 3,000	1.76	Good	-65 +135	Good
Polysulfone	--	10,000	50-100	1.24	Good	-65 +150	Good
Polyimide Film	KAPTON	18,000	707	1.42	Excellent	-80 +260	Excellent
Polyester Film	Mylar	13,000	185	1.39	Excellent	-65 +120	Excellent
Polyimide Coated TFE	TFE/ML	3,000	150	2.2	Good	-80 +260	Good
Polyimide Coated FEP	FEP/ML	3,000	150	2.2	Good	-80 +260	Good
Polyarylene	--	13,200	140	1.3	Excellent	-65 +260	Excellent
Ethylene-Tetra fluoroethylene	Tefzel	6,500	100	1.70	Good	-100 +150	Excellent
Ethylene-Chloro-trifluorethylene	Halar E. CTFE	4,500	220	1.68	Good	-85 +150	Good

8.2.4 Conductor Lay Length

It is recommended that the conductor pairs be made up with a short lay length of approximately 1 to 1-3/8 inches. This will assist in improving cable flexibility and reduce the minimum allowable cable diameter. Cable flexibility is not usually a service requirement but it does assist in cable installation. Also, of greater importance, is providing as small an allowable cable bend radius as possible to facilitate location of outboard components in congested areas.

8.2.5 Shields

Where shields are required over twisted conductor pairs, a braided shield of number AWG 36 tin coated copper is recommended. The braid angle should be 35 degrees minimum, and the overall coverage should be specified as 85 percent minimum.

Shielded conductors are not recommended for outboard applications unless absolutely necessary for electrical considerations. The shields increase the cable diameter; increase cable, and cable termination costs; require additional contacts in the hull penetrator (and consequently additional hull penetrators) and have caused problems in past years due to unacceptable water-to-shield insulation resistance. In the early 1970's, outboard cable shielding requirements have been deleted by the Navy for many sonar systems. Shields were originally used in cable designs as the cables ran from the inboard electronics directly through the stuffing tube type hull penetrator (figure 5-20) to the outboard hydrophone or transducer. The shield provided electrostatic protection inboard from such sources as compartment fan brush noise. The cable shield on the outboard side of the hull is of little value as the salt water itself provides a better shield from electrostatic interference than the copper braid, also there is little or no electrostatic interference problems outboard.

8.2.6 Shield Insulation

The shield insulation can be comprised of a heat sealable polyester (Mylar) tape, applied helically and overlapped. This tape provides suitable insulation and does not appreciably add to the diameter of the shielded twisted conductor pair. In some cable designs, shield insulation is applied under the braided shield as well as over the shield. This would be recommended in flexible cable designs.

8.2.7 Cable Fillers

The valleys or interstices of the cable should be filled with a non-temperature sensitive rubber filler. Depolymerized rubber or silicone rubber can be used. The fillers should be capable of being readily removed for ease of terminating the cables. These fillers are placed in the cable to provide a round, firm, voidless cable that will not be deformed or displaced during connector molding operations. The filler also prevents the cable jacket from being over-stressed if subjected to deep sub-mergence hydrostatic pressures.

Cable and strand fillers which have been reported to provide an internally waterblocked cable are not recommended for use in submarine cable design. These types of fillers were useful when the cables were sealed at the components and hull penetrators with cable stuffing tubes. Now that these tubes have been replaced on deeper diving submarines, there is no longer any need for the "non-hosing" type cable. It should be noted that the cable has always been considered "non-hosing" when tested in conjunction with a stuffing tube.

8.2.8 Cable Core Binder

A cable core binder is necessary on certain cable designs to support and contain the cable bundle. An impregnated fabric tape such as neoprene-cotton, at approximately .010 inches thick, and applied half lapped is suitable for the application. This is used on MIL-C-915 MWF type cables.

8.2.9 Cable Jacket

Ideally, outboard cables should be jacketed with a tough, abrasion resistant, thick cross sectional jacket with low water permeability characteristics. The jacket material should also be bondable to the rubber molded boot materials used to seal the cable to the connector plug and receptacle. The jacket material must also be capable of withstanding the rubber molding temperatures. Recommended cable jacket thicknesses for outboard cables are noted in Table 8-4. Thick cable jackets are recommended as the jacket provides the sea water barrier and the jacket can and is subjected to possible abuse, physical damage and abrasion during submarine fabrication and overhaul periods as well as constant exposure to the seawater environment.

Cable jacket material selection is probably the most important consideration in outboard cable design. At this time arctic neoprene is the cable jacket material most used on submarine outboard cables as it is specified in MIL-C-915. In the past ten years, however, polyurethane, butyl, Hypalon, polyethylene, ethylene propylene and polypropylene materials have been used on outboard sonar system cabling. (Antenna cable is primarily polyvinyl chloride jacketed MIL-C-17 coaxial cables. Towed sonar arrays also use various types of cable jacketing materials.

It is difficult to speculate at this time which cable jacketing materials will ultimately be selected for primary use in outboard cables. A cable design, test and evaluation program is definitely indicated in this area. Perhaps the new design polyurethane and polyethylene jacket cables presently being used on TRIDENT submarine construction will provide the answer for the future decades.

8.2.9 (Continued)

The polyurethane materials currently specified for TRIDENT cabling is as follows:

1. B.F. Goodrich Company (ESTANE 58300)
2. Mobay Chemical Company (TEXIN 985A)

The TRIDENT polyethylene cable jacketing material is a copolymer supplied by the Union Carbide Corporation, No. DFDA-0588, black 9865.

TABLE 8-4

RECOMMENDED OUTBOARD CABLE JACKET THICKNESSES

Cable Core O.D. (Inch)	Wall Thickness + 10% (Inch)
Up to .375	.062
.376 to .625	.093
.626 to 1.000	.125
1.001 to 1.250	.156
1.251 to 1.500	.187
1.501 to 1.750	.218
1.751 to 2.000	.250

8.2.10 Electrical Requirements

Electrical requirements for outboard cables may vary for each sonar system design. However, a 500 megohm insulation resistance per 1000 ft. of manufactured cable is recommended for conductors to conductors, conductors to shield, and shield to water taken at 500 volts DC. A 3000 volt AC (rms) withstanding voltage test is suggested for conductor to conductors; 1000 volts, conductor to shield, and 500 volts, shield to water. Conductor resistances should meet ASTM standards for each particular AWG size used. Mutual capacitance (picofarads per foot at 1 kilohertz maximum), maximum percentage capacitance unbalance, and characteristic impedance at one megahertz should be specified in the individual cable specification sheets as required in each sonar system design.

8.2.11 Environmental Requirements

Environmental requirements for outboard cables should include a two hour hydrostatic pressure test of the finished cable at 1-1/2 times the operating depth of the cable end use. A -40°C ± 2°C bending endurance test on a suitable diameter mandrel is also recommended as is an air oven test at 165°F on a suitable diameter mandrel. No cable damage should be evident as a result of these tests. Tensile strength and elongation tests are also recommended to be conducted on the conductor insulation and cable jacket. It is noted that the cable must be capable of withstanding an accelerated life test when tested as part of a cable harness which is mated to a hydrophone or transducer assembly being subjected to these series of tests. These tests include temperature/air, temperature/sea water, thermal cycling, pressure/sea water, pressure cycling/sea water, vibration and explosive shock (see Reference 8-15). The cable must be resistant to corrosion in a sea water environment.

8.2.12 Physical Requirements

Physical tests for outboard cables should include cable breaking strength. This is required for cables that are directly molded to the sonar components as it is possible for the technician or assembler to pick up the hydrophone or transducer by the cable. A breaking strength test is also quite naturally required for towed sonar array cables. The cable should also be tested for abrasion resistance and impact strength as the cables may be subjected to these abuses at installation on a submarine. The cable must also be able to withstand a hydrostatic pressure test equivalent to 1-1/2 times the maximum operating pressure. The cable should be capable of withstanding 2000 hydrostatic pressure cycles at the specified maximum submarine operating depth. The cable should also be capable of withstanding high impact shock and vibration tests as well as normal abuse in handling, installation, service, and maintenance.

8.2.13 Cable Types and Sizes

Every effort should be made to keep the number and types of cables used outboard on submarines to an absolute minimum. The cable footage used outboard is not great when compared to the inboard cabling. Manufacturing costs can be reduced if a small number of cable types are designed and used. Also, the cable diameters should be standardized as much as practicable tc facilitate connector boot mold designs and to reduce mold tooling. The cable should be as light as practicable, especially when used on Deep Submergence Vehicles. The cable diameter should also be as small as practicable to facilitate installation and minimize the bend radius.

8.2.14 Cable Specifications

Specifications prepared for outboard cables should be very detailed with respect to construction, material selection, and testing, which includes qualification and quality conformance.

The cable specification should detail conductor materials and coatings, conductor stranding, conductor insulation materials, lay up sequence, lay direction and lay lengths, conductor identification, shielding braid material and coatings, braid angles percent of braid coverage, braid insulation materials and application method, filler materials, core binder materials and application method, jacket material, thickness, cable diameter and cable marking.

The detailed specification will insure that cables manufactured by one company will be identical to cables manufactured by another company. If the cable specification is only performance oriented, then proper termination of connectors to the cables cannot be standardized and proper wiring and molding methods cannot be assured.

8.3 Submarine Outboard Cable Designs

Large quantities of outboard cables have come into use on submarines since 1945, due to the increase in sonar systems located outboard of the submarine pressure hull. Over 90 percent of cables used outboard on submarines service sonar system components. The TRIDENT submarine employ over 1300 outboard cables. As noted earlier many cable types have been used in the past four decades. The following paragraphs discuss the past successes and problem areas in outboard cable design and offers recommendations for future design improvements.

Many types of cables have been run outboard on submarines in the past forty years. The SS type cables specified in MIL-C-915, Reference 10-1, have been the cables in predominant use. These cables have synthetic tubber insulated copper conductors and neoprene cable jackets. They are internally waterblocked. In some cases Hypalon cable jacket material is allowed. The few coaxial cables that are used in design in accordance with MIL-C-17, Reference 8-2. These cables usually have polyethylene insulated conductors and a polyvinyl chloride cable jacket.

In more recent years, the Naval Weapons Support Center, Crane, Indiana, has employed a Butyl jacketed DSS-3 type cable in an effort to enhance performance of the AN/BQR-19 sonar system. Also, the use of polyethylene encapsulated hydrophones on TRIDENT submarines has required the use of a polyethylene jacketed cable. The TRIDENT submarine is also using Tefzel insulated conductor, polyurethane jacketed cables in a general effort to improve the outboard cable designs.

A number of deep submergence vehicles are using oil filled outboard cables. One of the first and most notable of these is Alvin. (Reference 8-3). Also, one of the DSRV vehicles is presently being outfitted to make use of oil filled cable assemblies. Reference 8-4 discusses oil filled cable designs for a submersible with a 20,000 foot maximum operating depth.

8.3 (Continued)

The TRIESTE deep submersible, many years ago, was designed to use PYROTENAX mineral insulated cables. The use of mineral insulated cables, however, has not seen wide use - possibly due to installation difficulty and unavailability of shielded pair, coaxial and multi-conductor (over seven) cable designs. Trieste currently uses standard MIL-L-915 and commercial SO type cables.

8.4 Deep-Submergence Vehicle (DSV) Outboard Cable Design

Deep submergence vehicles (DSV) and underwater oil exploration systems are making use of pressure balanced oil filled cables. A patent, Reference 8-9, was granted on one of those designs in 1977. The oil filled cables are terminated to connector plugs with the contacts glass sealed or sealed with O-rings. A self closing check valve is sometimes located in the plug-header to allow the compensating fluid to fill the plug-receptacle interface. The cable jacket can be a transparent polyurethane tubing interference fitted to the ends of the plug. The tubing is retained on the plug adapter with hose clamps fabricated from type 316 stainless steel. A stress member made of high strength wire is usually routed inside the tubing along with the conductors. It is fastened to the plug boides to preclude mechanical stress being applied to the cable jacket or the conductors when handling the cable. The copper conductors are insulated with Teflon or Kapton insulation and the tubing is filled with an insulating oil through an O-ring seal port in one plug and vented in a similar port in the other plug. The oil also fills the strands of the conductors. MIL-H-5606 hydraulic oil has been used successfully in a number of applications.

When the cable is subjected to hydrostatic pressure, the pressure is readily transmitted through the wall of the elastomeric tubing into the fluid. This equalizes the pressure inside and outside of the jacket to prevent Z kinking. The low differential pressure across the tubing wall reduces the tendency of the seawater to permeate through the wall into the insulating fluid. There is little cable volume change with changes in pressure as the insulating oil has a high bulk modulus and the cable assembly is almost completely filled with fluid. The stresses in the cable jacket, conductors, and contacts are primarily compressive. The plugs at the ends of the cable carry the full hydrostatic pressure load at

the glass sealed contact header assembly or apply the full pressure load at the receptacle.

These type of pressure compensated, oil filled cable harness assemblies are fabricated by D.G. O'Brien, Inc., Seabrook, NH. See Figure 8-3. Additional details of design are offered in References 8-10 through 8-14. To date, these cables have been used on a Cameron Iron Works blow-out preventor system, Deep-star 20,000 DSV 4, DSRV and variations of this system are being used on DSV ALVIN and the CURV vehicles. It should be noted that the higher cost of the connector assemblies is more than offset by the lower "cable" costs as well as the harness assembly costs. The long lead time necessary for fabricating the standard cable is also eliminated. This type of cable is more easily maintained and repaired and does not require stocking a large number of cable types and sizes as with the standard type cables.

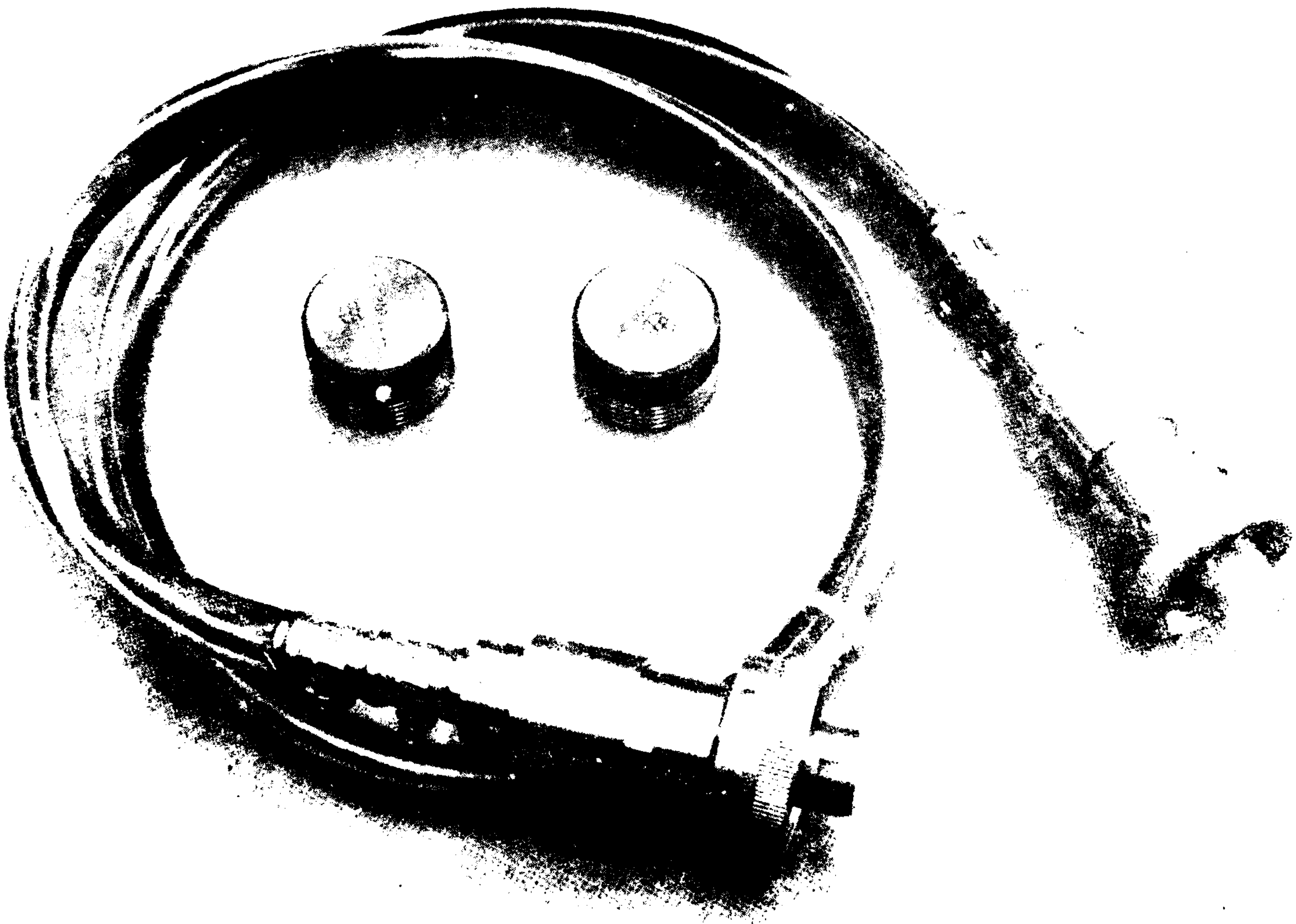


FIGURE 8-3 D.G. O'BRIEN, INC., PRESSURE BALANCED OIL FILLED CABLE HARNESS

REFERENCES

8-1 MIL-C-915, "Cable and Cord, Electrical, for Shipboard Use, General Specifications for"

8-2 MIL-C-17, "Cables, Radio Frequency, Flexible and Semi-rigid, General Specification for"

8-3 Hosom, D., "Oil Filled Electrical Cables External to Pressure Hull on DSV Alvin", Oceans, 1976.

8-4 O'Brien, D.G., "Pressure-Compensated Electro-Connective Systems for Outboard Usage on Deep Submersibles", IEEE Engineering in Ocean Conference, San Diego, CA, 1971.

8-5 "Handbook of Electrical Cable Technology for Deep Ocean Applications", Naval Ship Systems Command, Washington, D.C., 20360, AD877-774, November, 1970.

8-6 ASTM B3, "Soft or Annealed Copper Wire"

8-7 ASTM B33, "Tinned Soft or Annealed Copper Wire for Electrical Purposes"

8-8 ASTM B286, "Copper Conductors for use in Hook-Up Wire for Electronic Equipment"

8-9 O'Brien, D.G., & Walker, E.R., "Pressure Compensated Marine Electrical Cable Apparatus", Patent No. 4,003,620, January 18, 1977.

REFERENCES

(Continued)

8-10 Miller, W.C., Jr., "A High-Reliability Oil-Filled Cable Harness Assembly for Use on an Underwater Blow-Out Preventer System", Offshore Technology Conference, Houston, TX, May, 1977.

8-11 O'Brien, D.G., "Pressure-Compensated Electro-Connective Systems for Outboard Usage on Deep Submersibles", IEEE Engineering in the Ocean Conference, San Diego, CA, 1971.

8-12 Saunders, W., "Pressure-Compensated Cables", 8th Annual Marine Technology Society Conference, 1972.

8-13 Edwards, F.L. & Patterson, RA., "Pressure Balanced Electrical Hull Penetrators and External Cabling for Deepstar 20,000", Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

8-14 NAVSEA DRAWING No. DSV 4-304-5155928, "General Specifications for Connectors, Oil-Filled for Deep Submergence Vehicle Cabling", Mare Island Naval Shipyard, Vallejo, CA.

8-15 Carson, D.L., etal, "Composite-Unit Accelerated Life Testing (CUALT) of Sonar Transducers", Naval Ocean Systems Center Technical Report, TR 516, San Diego, CA, 92152, September, 1979.

(Blank)

SECTION 9

CABLE HARNESS DESIGN

LIST OF FIGURES

LIST OF FIGURES (cont'd.)

LIST OF TABLES

9.1 Introduction

The engineer responsible for the outboard electrical harness design on a submersible must have the following information prior to the initiation of the design and development program:

(a) Submarine operating depth,
(b) Submarine test depth,
(c) Shock requirements,
(d) Vibration requirements,
(e) Submarine temperature ranges - operating, storage, and transit,
(f) Space limitations outboard,
(g) Submarine service life,
(h) Submarine fabrication schedule,
(i) Assigned harness weight approximation,
(j) Anticipated vehicle cost and budget for harnesses,
(k) Outboard harness data sheet (see Table 9-1),
(l) Submarine maintenance schedule,
(m) Accessibility of harnesses.

TABLE 9-1

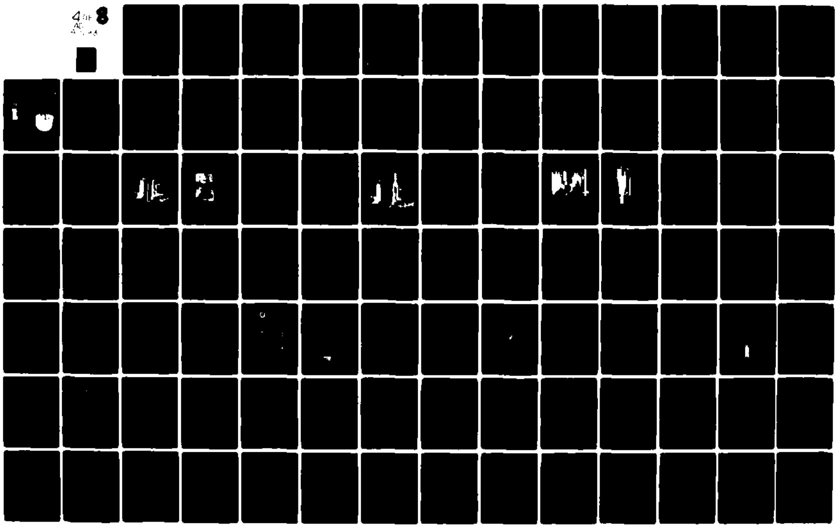
Typical Outboard Electrical/Electronic Cable
Harness Data Sheet

1	Component Name:
2	Component Voltage Requirements:
3	Component Amperage Requirements:
4	Component Operating Frequency:
5	Component Electrical and Acoustical Interface Requirements:
6	Component Impedance Requirements:
7	Outboard Component Harness Length:
8	Outboard Component Harness Plugs Or Receptacles:
9	Outboard Component Harness Cable:

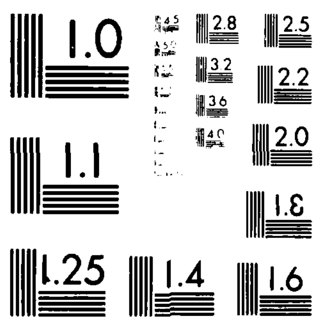
AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

UNCLASSIFIED NRL-MR-4601 NL

4 of 8



1193



MICROCOPY RESOLUTION TEST CHART

The preceding list gives the engineer the data required to select components such as connectors (plugs or receptacles), cables, and connector termination techniques.

9.2 Pressure-Proof Cable Harness Types

Five basic electrical harness designs have been used outboard in the past 40 years. (See Figure 9-1), They are:

1. Internally water-blocked neoprene-jacketed cable molded directly to the component and sealed at the hull in a stuffing tube-type fitting.
2. Neoprene-jacketed cable with connectors molded to each end. The connector plugs into the component and hull penetrator receptacles.
3. Mineral-insulated, metal-sheathed cable brazed or potted to the component and to the penetrator body.
4. Polyethylene-jacketed cable molded or connectorized to the component, and polyethylene-molded boot sealed to the hull penetrator. The cable may be spliced to suit installation requirements.
5. Oil-filled cable running from a component to a distribution center and then to the hull penetrator. The oil is blocked at the penetrator and usually at the component.

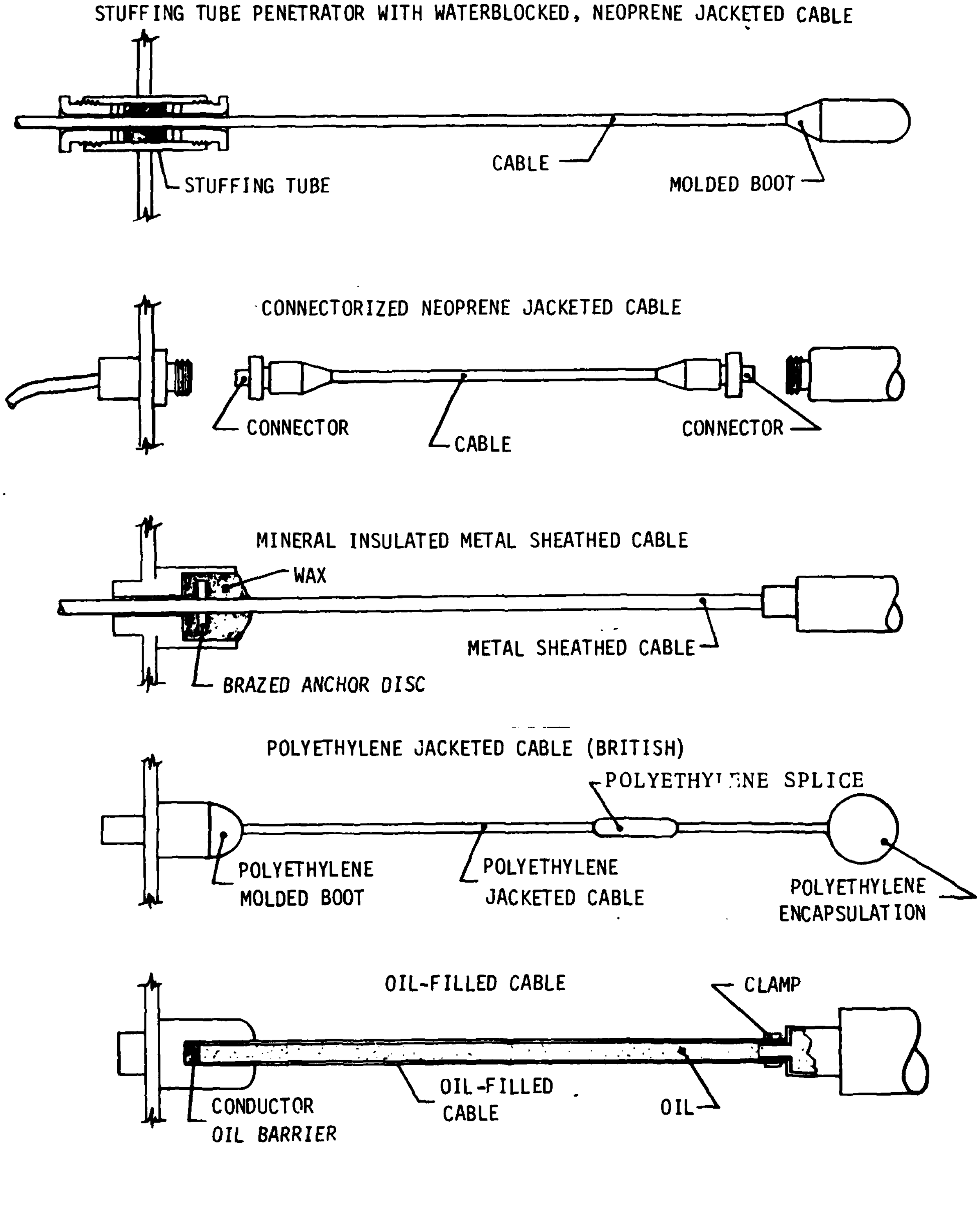


FIGURE 9-1 PRESSURE-PROOF HARNESS DESIGN TYPES

9.2 (Continued)

Of all the basic harness designs that can be considered for underwater use, those which utilize electrical connectors at both ends of the cable are recommended. These connectors provide the following:

(a) They provide a detachable interface between the electrical/electronic component manufacturer and the vehicle manufacturer (or the user).

(b) They provide a convenient and necessary electrical test point for the component during various stages of manufacture, testing, installation and maintenance.

(c) They allow proper packaging of the electrical component for handling, packing, shipping, storage, and installation.

(d) They eliminate the need for the component manufacturer to provide the electrical cable to a distant, unknown junction point.

(e) They provide a proper interface for maintenance and replacement of electrical components and harnesses.

(f) They provide a proper interface between components in a complex outboard electrical system.

(g) They facilitate the manufacture, handling, and assembly process of components.

(h) They provide for the pressure-proof seal[illegible] of an electrical component.

(i) They facilitate the hydrostatic pressure testing of outboard components and penetrators.

(j) They allow a component to be removed from the system without draining oil from that component or other components; or opening the component to disconnect the cable.

9.2 (Continued)

(k) They provide separation for components using different fluids and for incompatible components (i.e., motor/controller).

(l) They allow the component to be filled with fluid before installation on the vehicle.

Harnesses which utilize internally watertight neoprene-jacketed cables (MIL-C-915) molded directly to the component and sealed to the hull with stuffing tubes are not considered by the U.S. Navy for use on vehicles with operating depths greater than 400 feet except for the TR-155 (type) BQS transducers.

Metal-sheathed mineral-insulated cables are not seriously considered, despite the excellent physical protection they provide, because the cables are relatively inflexible and difficult to install in the cramped spaces of a submersible superstructure. They also pose handling problems to the component manufacturer and are limited in the types and sizes available.

Polyethylene or rubber-jacketed cables molded directly to the hull penetrator and to the component are a satisfactory harness design for underwater applications. The cable is usually spliced at the component or penetrator to facilitate assembly of the harness. This type of harness provides a more "tamper proof" assembly, but does not offer the required flexibility as noted earlier with a connectorized harness. With systems using these type harnesses, the low density polyethylene-jacketed cables offer the advantage of a high dielectric material in a salt water environment. These harnesses have been used by the British Navy who have developed suitable polyethylene-to-metal bonding techniques. Most U.S. designs of this type have been made use of

9.2 (Continued)

neoprene-jacketed cables, neoprene molded splices, and neoprene-to-metal bonding techniques because these cables are readily available in the U.S. Also, the neoprene-to-metal bonding technology is widely used and well advanced in this country Neoprene does not possess the dielectric and low water absorption properties of polyethylene.

9.3 Harness Design Factors

The primary function of an outboard pressure-proof harness assembly is to provide an electrical interconnection point from the electrical hull penetrator to the outboard electrical/electronic component, or from an outboard distribution center to the component.

As seen earlier, many basic designs have been used in the past 40 years to satisfy the requirements. The harness configurations used in the past years have been primarily based on cable availability and the large number of cable types required for each vehicle design. This problem is being solved with the development of various cable types and sizes under various Navy programs. These cables, together with connectors under development, will result in a well-designed harness assembly.

The design factors listed in table 9-2 must be considered in developing a pressure-proof harness assembly:

Table 9-2 Cable Harness Design Factors

1. Material of Construction
2. Cable Strain Relief
3. Conductor Terminations
4. Hydrostatic Pressure
5. Weight
6. Cable Diameter
7. Service Life
8. Shock and Vibration
9. Cable-to-Connector Boot Seal

9.3.1 Materials of Construction - Materials used in the harness fabrication must be resistant to corrosion in a sea water environment.

9.3.2 Cable Strain Relief - Cable strain relief must be provided at the cable-to-connector interface. The connector boot must have strain relief provisions to withstand repeated cable flexing while maintaining a watertight bond between the cable/boot transition; and a watertight bond between the boot/connector shell transition.

9.3.3 Conductor Terminations - All conductor terminations within the plug or receptacle shell cavity should be fully supported and sealed. This combined moisture barrier and conductor strain relief is readily accomplished by the use of epoxy or polyurethane potting compounds. As a general rule, epoxy should be used at pressures in excess of 1500 psi. Insofar as it is possible, the method of connecting conductors to contacts shall be via crimping rather than by soldering. The connector wiring and molding design should be such that the conductors will not be hindered in the wiring operation or under hydrostatic pressure cycling conditions. Connector potting compounds should be specified that have minimum curing shrinkage properties. Standard military approved tools should be specified for crimping conductors to contacts. Tools for stripping (removing) insulation from conductors should be capable of removing the insulation without damaging the underlying wires. Thermal stripping tools are recommended.

9.3.4 Hydrostatic Pressure - The harness assembly must be capable of withstanding a hydrostatic pressure test equal to one and one-half times the maximum operating pressure. The harness assembly, when mated to the counterpart connectors, should be capable of withstanding 2000 hydrostatic pressure cycles at the specified operating depth.

9.3.5 Weight - The harness assembly must be as lightweight as practicable when used on Deep Submergence Vehicles.

9.3.6 Cable Diameter - The harness cable diameter and overall diameter of the connectors and molded boot should be as small as practicable. The small size will facilitate harness location and installation and provide for a smaller cable bend radius.

9.3.7 Service Life - The service life goal of a harness assembly should be ten years within the mission profile. The harness should not need replacement from one major ship overhaul to another. The harness should be designed to withstand the abuse encountered in handling, installation, and maintenance.

9.3.8 Shock and Vibration - Harnesses should be capable of withstanding a high impact shock (MIL-S-901) and a vibration (MIL-STD-167) test without physical damage, loosening of component parts, or discontinuities in the electrical circuits.

9.3.9 Cable-to-Connector Boot Seal - The connector boot should be designed to allow the cable to bend at its specified minimum radius, at the junction point of the cable and connector. The connector boot materials and potting compounds should be readily available and not require extensive handling and use precautions. The connector boot mold should be a simple design and not have assembly and use problems. Boot molding must completely cover and fill the connector backshell and overlap the cable and any potting ports. Adhesives and primers used to seal the connector boot to the cable jacket and connector shell must provide a tenacious bond in a sea water environment for the required service life of the harness. Loss of bond at the rubber-to-metal interface while in sea water service has been the most troublesome failure area in outboard cable harness use to date. Every effort should be made to make use of solvents and materials which do not require special safety precautions or cause skin irritation to the technicians using them. Wiring, potting, molding, inspection and test procedures should be as simple and direct as practicable.

9.4 Cable Harness Wiring and Molding Design

This phase of the pressure-proof harness design is considered to be the most demanding since it requires the "marrying" of a connector to a cable. (See Figure 9-2). This interface area is critical because the interconnection is subjected to cyclic hydrostatic pressures in service, and the assembly of the two components is not better than the care with which the joint is made. Two basic functions are accomplished when terminating a cable: the cable conductors are electrically connected to the connector contacts, and the cable is sealed to the connector to ensure a pressure-proof joint.

9.4.1 <u>Pressure-Proof Harness Integrity</u> - The pressure-proof cable-to-connector joining is critical to harness reliability. Marginal fabrication techniques will result in early seal failure; therefore, strict conformance to recommended procedures is mandatory. This conformance must be ensured by detailed in-process inspection. Areas of particular concern include surface preparation, condition of primers and adhesives used, and maintenance of contaminant-free surfaces throughout the molding process. Quality assurance documentation should include serialization of each molded cable seal for traceability and service life consideration.

The configuration of the molded cable seal can also affect seal reliability, particularly to a right-angle configuration where in-service cable flexing or retention devices close to the cable seal can exert constant and critical stresses on a relatively small bond area. These stresses can accelerate environmental attack on the bond and reduce life expectancy accordingly. Generally speaking, the elastomer-to-metal bond, whether the rubber be neoprene or polyurethane, undergoes a deterioration

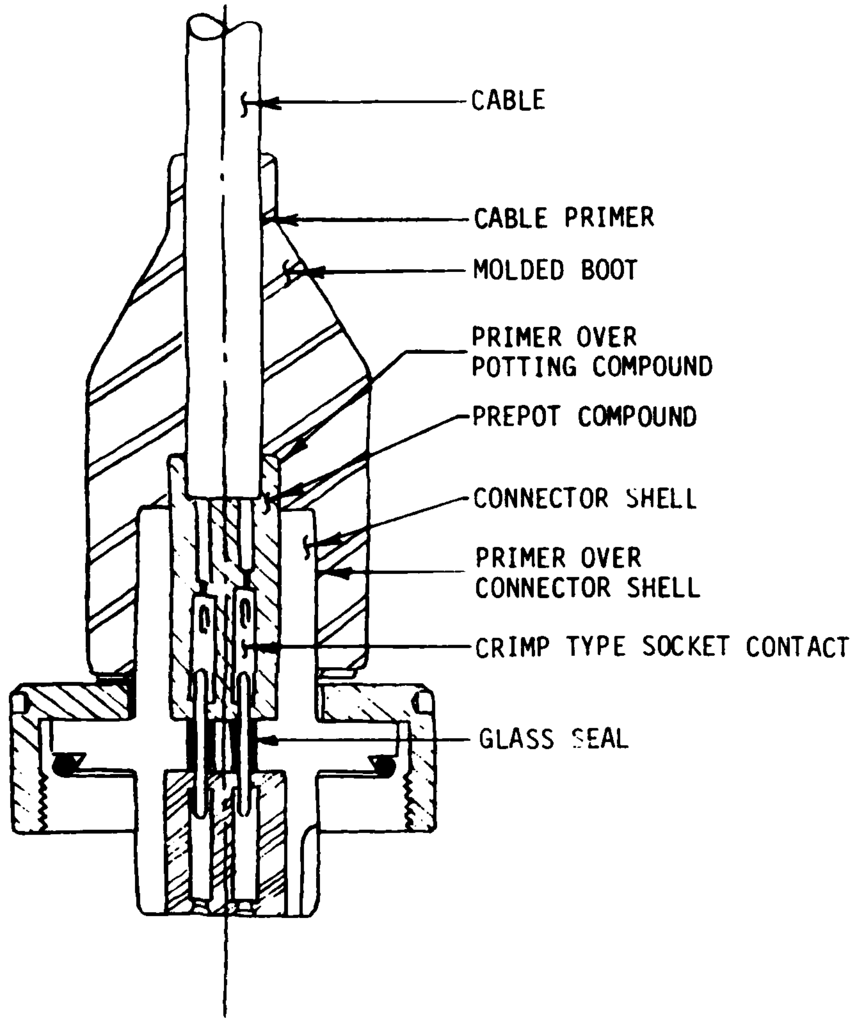


FIGURE 9-2 TYPICAL MOLDED PLUG ASSEMBLY

9.4.1 (Continued)

process when submerged in salt water. This process takes place over a period of years. Any mechanical or chemical means by which the rate of this environmental attack can be reduced will extend the service life accordingly.

9.4.2 Conductor Support - Experience has shown the need for proper support of conductors in the area adjacent to their termination contacts. Without this support, conductor strand buckling with eventual fatigue failure develops, with pressure cycling. This buckling occurs just above the contact crimp; in a soldered termination, it occurs where stresses concentrate at the outer extremity of the solder flow. This mode of failure is most evident where the conductor terminates within the bore of the plug shell. Figure 9-3 shows two insulators (with contacts) removed from plugs of this type after actual service. The terminated contacts have been withdrawn (small insulator) from their normal position in the insulator to expose the problem area. Both conductor terminations show the typical development of a "compression helix" adjacent to the crimp barrel of the socket contact. This "compression helix" represents the first stage of the developing failure. Clearance between conductors and insulator, and cold flow of conductor insulation, allowed this conductor deformation to take place. Metal fatigue from pressure cycle flexing eventually resulted in conductor severance close to the contact.

The larger insulator illustrates the same mode of failure in a soldered termination. In this particular case three of the four conductors had become discontinuous, and the fourth shows the initial stage of failure development. Aspects of the design which allowed this type of failure to occur include the following:

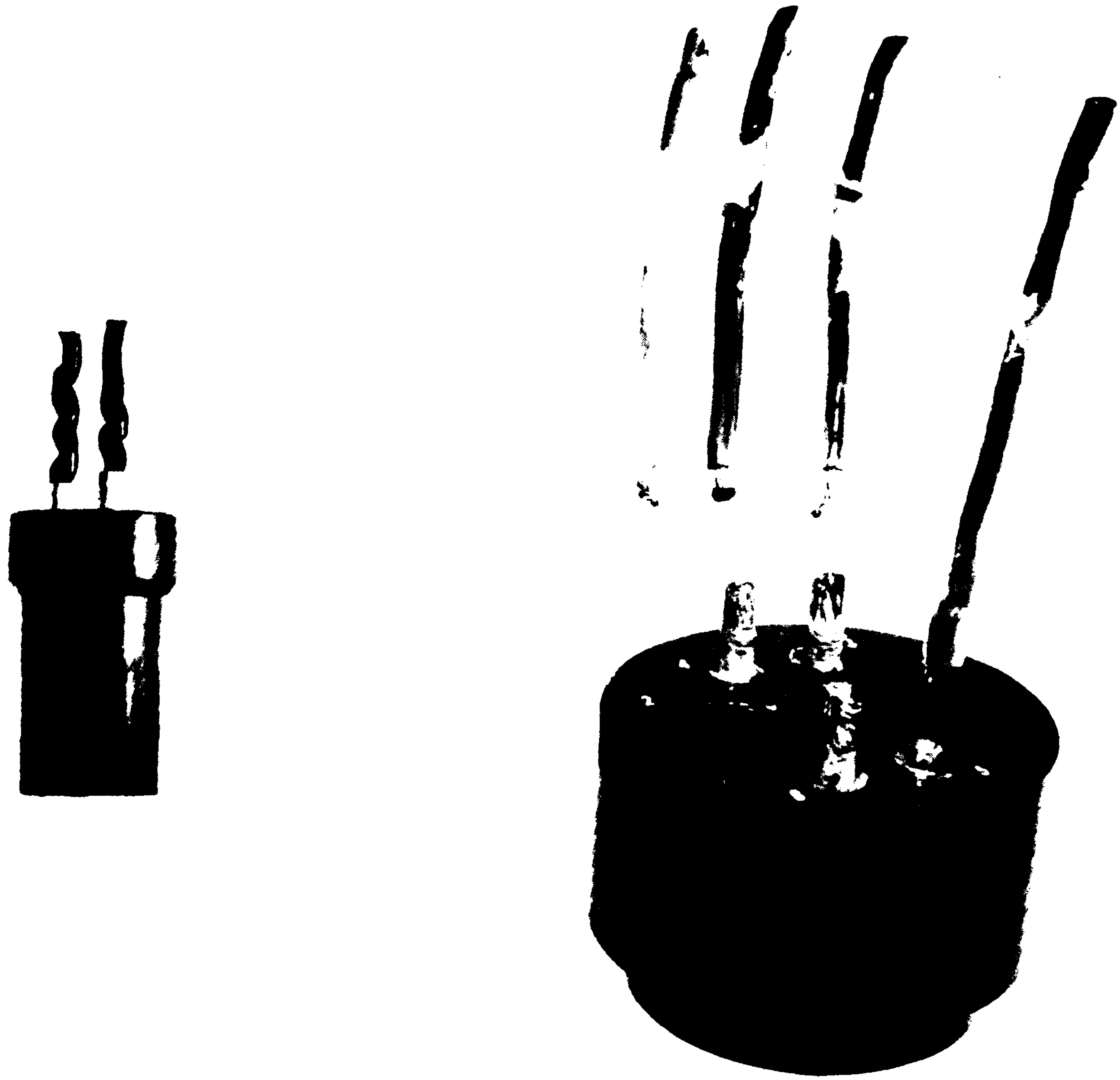


FIGURE 9-3 VIEW SHOWING PLUG CONDUCTOR FAILURE FOLLOWING CYCLING HYDROSTATIC PRESSURE TESTS

9.4.2 (Continued)

(a) Excessive clearance between conductor insulation and plug insulator.

(b) This clearance filled with low bulk modulus silicone rubber.

(c) Shrink tubing applied over a rather soft conductor insulation allowed conductor displacement within the insulation envelope.

It is recommended that molding procedures contain technician qualification requirements (see 10.16) to ensure that the technician is indeed familiar with the process and qualified to execute the techniques required to make up a harness.

In addition to the usual wiring schematics and step-wise fabrication procedures, certain other elements are essential to a good manual. These include such quality assurance measures as:

(a) Verification of fit with mating counterpart before and after molding.

(b) Examination of seal surfaces and threads.

(c) Examination of cable for jacket defects or damage that could result in a flooded harness.

(d) Inspection and test procedures including in-process and post fabrication testing.

(e) Handling and packaging.

(f) Specification of cable and connector components.

9.5 Molded Boot and Potting Compound Material and Process Considerations

9.5.1 <u>Molded Boot Material and Process Selection</u> - The molded cable-to-plug boot seal provides lateral cable support, restraint in tension, and the primary seal against water and moisture penetration. Basically, the seal is automatic in nature and dependent on three factors:

(a) The bond between the conformal boot seal and the connector shell.

(b) The bond between the boot seal and the cable jacket.

(c) The elasticity and resilience of the boot seal itself.

(d) Overlap of the molded boot on the cable and connector shell.

Three processes are used for fabricating cable boot seals. For neoprene-jacketed cables, compression molding (with or without a transfer operation) and urethane casting (molding) are common. With polyethylene-jacketed cable, transfer molding with polyethylene is standard practice.

The functional performance and reliability with neoprene or urethane type cable seals are related to a number of physical properties of the cured compounds. These include:

(a) Tensile strength
(b) Ultimate elongation) Toughness Index
(c) Tear strength)
(d) Modulus of elasticity
(e) Moisture permeability
(f) Water absorption

9.5.1 (Continued)

(g) Electrical properties
(h) Adhesion to metals
(i) Adhesion to cable jackets
(j) Environmental stability

1. Changes in physical properties
2. Changes in adhesion
3. Changes in electrical properties

The physical properties are fairly self-evident. Experience gained from various design/development programs in underwater connectors and related hardware, including observations after long-term service, shows some properties to be more important than others.

At depths down to 2,000 feet, the physical property profiles of medium hardness, low water absorption neoprene compounds and 70-80 Shore A durometer polyether-based urethane compounds have been satisfactory without prepotting. At deeper depths, the need for prepotting with a higher modulus, lower void material has been established.

9.5.1.1 *Neoprene Boot Seals* - Compression and transfer molding with neoprene compounds have long been utilized for molding connector seals in underwater applications (Reference 9-1) The cured properties of neoprene compounds, especially when compounded for low-water absorption, have resulted in connector seals with excellent long-term performance. Adhesive systems for bonding neoprene compounds to metals and cured neoprene cable jackets provide high performing rubber tearing bonds under a broad range of process conditions.

A neoprene compound which has been successfully used by the U.S. Navy in this application is noted in Table 9-3.

TABLE 9-3

Neoprene Molding Compound

Components	Parts By Weight
Neoprene WRT	80.0
Neoprene KNR	20.0
Neozone D	2.0
Stearic Acid	0.5
FEF Black	15.0
MT Black	30.0
Light Process Oil	4.0
Red Lead	20.0
Thionex	2.0
Sulfur	1.0

NOTE: 1) THE COMPOUND IS SUFFICIENTLY SAFE TO ALLOW INCORPORATION OF ALL INGREDIENTS AND STILL PROVIDE GOOD STORAGE LIFE AND HANDLING CHARACTERISTICS. FOR MAXIMUM STORAGE LIFE, THE MATERIAL SHOULD BE KEPT IN A COLD ROOM 40°F OR BELOW.

2) FROM REFERENCE 9-1.

3) MOLDING TEMPERATURE 305°F ± 5°F.

9.5.1.1 (Continued)

The Dayton Chemical Products Laboratories, West Alexandria, Ohio, metal primer, Thixon P4, in conjunction with the Thixon adhesive, Thixon NM-2*, has provided satisfactory bonds of neoprene to stainless steel connector shells. The Hughson Chemical Co. Chemlok 205 and 220 adhesives have also provided satisfactory bonds.

9.5.1.2 *Polyurethane Boot Seals* - Presently, the use of polyurethane is increasing in fabricating underwater cable seals. This may be attributed to a number of factors:

(a) Low compound viscosity permits casting or molding at low pressure with less potential of voids.

(b) Low or intermediate temperature curing is within the temperature limitations of all insulating materials.

(c) Tooling and process control with urethanes are not as critical as in the compression or transfer molding of neoprene.

(d) Transparent (amber) polyurethane allows visual inspection for defects such as loss of bond to the metal or rubber, inclusions or bubbles. It also provides visual evidence that the adhesives or primers have, in fact, been applied.

Presently, polyether-based polyurethane materials in accordance with military specification MIL-M-24041 (Reference 9-2) are used successfully in cable-to-connector sealing applications. This

*Now Thixon 100

9.5.1.2 (Continued)

specification also gives satisfactory polyurethane primers for bonding the urethane to metal and neoprene or polyvinyl chloride cable jackets. A Qualified Products Listing (QPL) accompanies this specification.

Finally, the area of adhesion performance and environmental resistance cannot be over-emphasized. Cable seal failure after a design has been adequately tested and proven can be traced invariably to poor bonding. The latter may be due to improper screening and process selection or to poor shop practices. When molding urethane to connectors, the primers and urethane specified in the QPL listing of MIL-M-24041 should be used. Shop practices that may contribute to poor bonding performance include: poor surface preparation, contamination, inadequate proportioning of two-part primers, and use of depleted or over-aged materials, and hastening two part primer cure using external heat such as a heat gun.

Metal surface preparation should include vapor phase degreasing before and after grit blasting with a clean, relatively coarse, non-ferrous grit. The residual grit and small metallic fines should be completely removed from the blasted surface. These can be blown off with clean, dry, oil-free filtered, compressed air and then wiped with a clean towel wetted with trichloroethylene. At no time should the surfaces to be bonded be touched or handled. Metal surface preparation should be performed just prior to bonding. Cable jacket surfaces should be lightly wiped with a volatile active solvent such as trichloroethylene or trichloroethane, then roughened with a clean, coarse open-grit emery cloth or piece of sanding disc. The surface should be lightly dusted off with a clean dry brush or wiper, and lightly wiped with the solvent once again.

Some facilitites use a solvent-wiping technique on metals. In this operation, the pieces are progressively swabbed with sol-

vent-moistened cloths and the solvent wiped off before it has time to dry. This operation requires oil-free solvent and clean, soap-free cloths (Reference 9-1).

Vapor phase degreasing is far superior to solvent-wiping. In vapor degreasing, the contamination is removed by a refluxing action in which the pure solvent vapor condenses on the cold workpiece, dissolves the contamination capable of solution, and drips off the connector shell. This action ceases when the metal reaches the vapor temperature, and it serves no purpose to leave the connector shell in the degreaser for a longer time.

Contamination of the metal surface can occur in handling or just standing in air. The primer can be contaminated during mixing or by improper resealing of the original containers. Containers, mixing spatulas, and application brushes should be solvent-wiped with a disposable wiper and clean solvent before use. *When handling solvents, always pour the solvent* out of the container; do not hold the cloth or wiper to the spout. The latter procedure could-possibly transfer contaminants to the solvent supply. Release agents are also a source of potential contamination. Without adequate direction, the typical technician applies too heavy a coat of a release agent, be it the silicone type or a fluorocarbon. With urethane compounds, one part Dow Corning DC-20 diluted with three parts of hexane provides a release system with minimum build-up when wiped on and quickly wiped off with disposable wipes. Spray type mold release agents are not recommended as they may contaminate parts to be bonded. Baked on Teflon coated molds are recommended.

Inaccurate weighing of two-part primers may sometimes provide less than optimum results. Many two-part primers have fairly broad latitude in mixing and when less than typical bonding

occurs, the possibility of a depleted reactive component should be investigated.

Isocyanate curing agents react readily with atmospheric moisture and lose some of their strength. Bottles and containers holding reactive components should be opened for as short a time as possible, their seal closure wiped, and then resealed.

9.5.1.3 *Polyethylene Boot Seals* - Polyethylene injection-molded cable seals to polyethylene jacketed cables are utilized in underwater applications because of a unique combination of excellent dielectric characteristics (particularly at high frequencies), high electrical resistivity, low moisture permeation, and low water absorption (References 9-3 and 9-4). The latter two characteristics contribute to the above electrical properties in a continuous water environment. Also, the initial material cost and thermoplastic processing capabilities of polyethylene resins offer important economic considerations when larger quantities are involved. While polyethylene offers specific advantages in the cable insulation and jacketing area, associated terminations and connectors present fabrication problems. This is because the most reliable long-term seal or bond to a polyethylene cable jacket is produced by molding with a similar type polyethylene: obtaining a fusion bond to itself. When a bond is required between a polyethylene seal and a metal shell connector or penetration, a process requiring closely controlled metal surface preparation and the molding variables of pressure, temperature, and time is involved.

Polyethylene resins are produced with a range of basic molecular properties such as average molecular weight, molecular weight distribution, and density. These properties, in turn, determine most mechanical properties, thermal processing characteristics, and environmental stress-cracking resistance. The latter environ-

mental factor is singled out because of its importance in most polyethylene applications. A property related to molecular weight, termed melt index, is a good index of a polyethylene resin's resistance to stress-cracking. Resins with low melt indexes have higher melt viscosities when molten and show better stress-crack resistance.

To obtain the highest mechanical and environmental resistance properties possible, polyethylene resins used in underwater cables and molded seals should be of the highest density type with low melt index. The high density, low melt index resins, however, are the most difficult to process. Even with proper resin selection, fabrication equipment design and process operation play a major role in the end result. Polymer degradation reflected in reduced mechanical properties and eventual stress-cracking can occur if incomplete melting occurs or if the material is heated to too high a temperature or for too long. Mechanical working of an incompletely melted polymer can also markedly raise the melt index and eventually lead to stress-cracking.

Other considerations in polyethylene-molded connector and penetrator seals include some limitation on the size and complexity of the seal by the nature of the material and process involved. High density, low melt index resins have high melt viscosities and require fairly high molding temperatures and pressures. On cooling, residual stresses formed in the part can combine with externally induced stresses to induce stress-cracking. The connector/penetrator design must take into account the wide difference in thermal coefficients between the polyethylene and metal. This situation, combined with the polyethylene's high elastic modulus, can cause appreciable stress to develop.

9.5.1.3 (Continued)

Many potential problems can be envisioned if the production of polyethylene cabling systems were attempted on a shipyard level. Molding polyethylene seals to connectors and penetrators, even if the type were small and simple, may be beyond shipyard capability. Clean rooms and extensive control of materials and processes are used by the few facilities that do this type of molding. If shipyard molding were confined to less critical in-line joint operations, special equipment and process controls would not have to be instituted. (Polyethylene cable splices are covered in Section 11 of this Handbook).

9.5.2 <u>Connector Potting Materials and Process Selection</u> - As noted earlier, polyurethane potting compounds, per MIL-M-24041, can be effectively used to pot connector internals to withstand vehicle operating depths of 2,000 feet. Beyond this depth, unfilled and filled epoxy compounds are recommended.

The glass filled epoxy compound noted in table 9-4 is felt to offer properties consistent with prepotting material requirements. These compounds were evaluated by the U.S. Navy under the DOT Program (Reference 9-5).

The commerically available compounds listed in table 9-5 are also deemed suitable for the application.

Table 9-4 Glass Filled Epoxy Compound Components

Component	Parts By Weight	Manufacturer
Sonite 41 Hardener	20 grams	Smooth-On Mfg. Co. 572 Communipaw Ave Jersey City, NJ 07304
ERL 2772 Epoxy Resin	100 grams	Union Carbide Corp. Plastics Division 270 Park Ave. New York, NY 10017
222-0803 Hardener	2 grams	Union Carbide Corp.
Milled Glass Fibers	90 grams	Owens-Corning Fiber-glass Corp. 717 Fifth Ave. New York, NY 10017

Table 9-5 Alternate Epoxy Compounds

Component	Parts By Weight	Manufacturer
Stycast 2651	100 grams	Emerson & Cuming, Inc. Canton, MA
Catalyst 11	8 grams	Emersion & Cuming, Inc.
Marblette Resin 121	100 grams	Marblette Corp. Long Island, NH
Hardener 91	10 grams	Marblette Corp.

In general, it is recommended that connectors be prepotted with a high compressive modulus epoxy compound, followed by molding the wired and potted assembly with primers and urethane specified in MIL-M-24041.

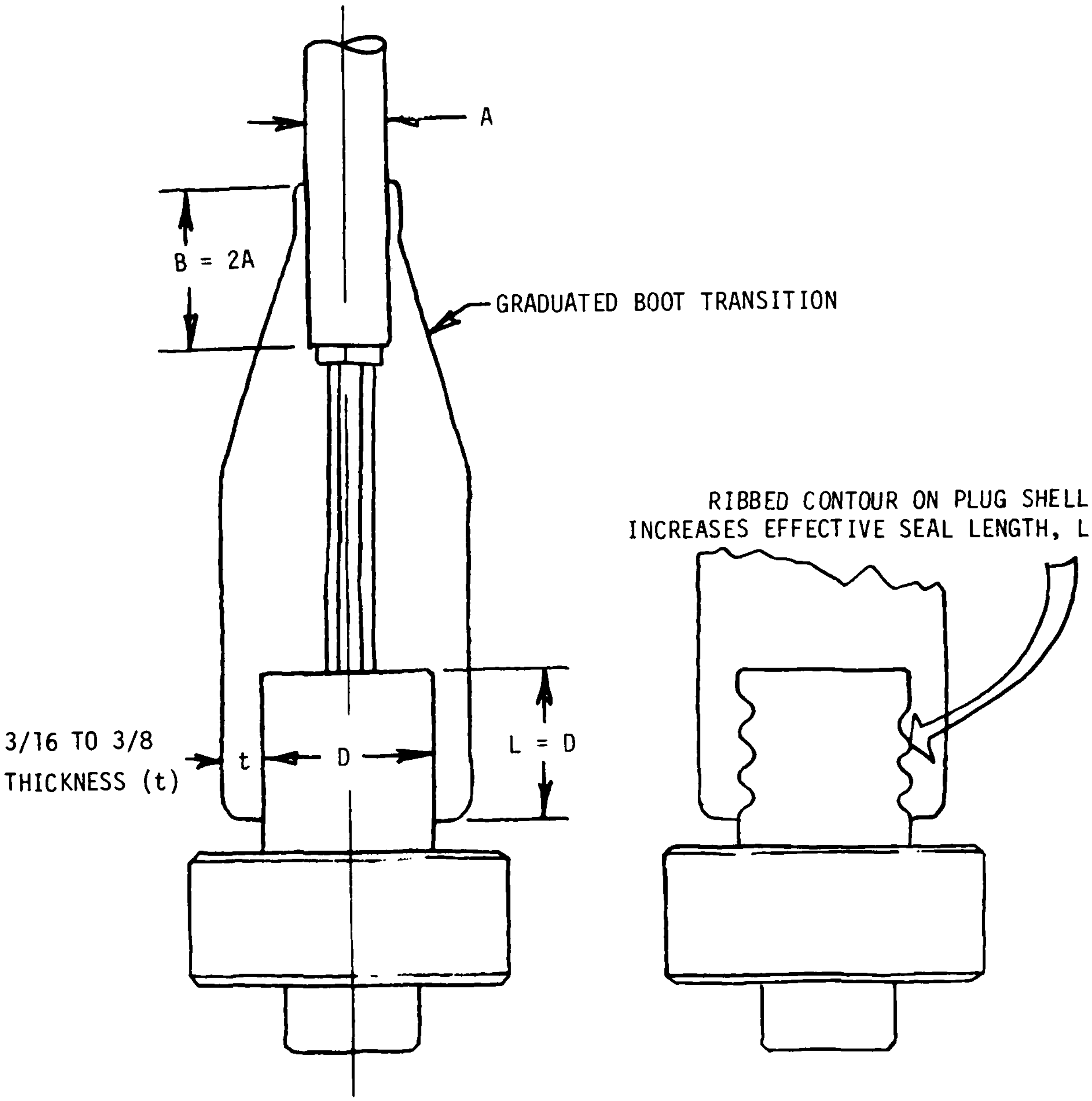
9.6 Mold Design

9.6.1 Cavity Configuration - The basic mold cavity configuration evolves from several factors; these include:

- (a) Anchoring of connector shell and cable in the molded boot.
- (b) Cable strain relief.
- (c) Encapsulation of prepot area.
- (d) Boot thickness.
- (e) Straight or right-angle cable entry.

The cable-to-connector seal or molded boot should have a configuration that minimizes any constant stresses in the rubber-to-metal bond that could result from flexing or securing the cable. Stresses of this nature applied over relatively long periods of time accelerate environmental deterioration of the rubber-to-metal bond. The length of seal on the connector shell shouid be at least equal to the shell diameter. A convoluted, or ribbed, machined shell in the bond area can also be considered to increase the surface bond area. (See Figure 9-4). The transition between connector shell diameter and cable diameter should be graduated to distribute the stresses on conductors and termination. All necessary prepotting of conductors in the boot area must be considered for proper sizing of the cable-to-plug sealing boot, which must adequately encapsulate this prepotting. An uninterrupted 360^{o} seal surface should be provided on both right-angle and straight plugs.

Sealing of more than one cable to a connector should be avoided wherever possible because it complicates both terminating and molding operations which must be accomplished within the fixed area, dictated by the plug shell diameter. Insufficient spacing between cables for a reliable seal is the usual result.



A = CABLE MAX. DIAMETER

B = CABLE BOND LENGTH

D = SHELL MAX. DIAMETER

L = SEAL AREA LENGTH

FIGURE 9-4 VIEW SHOWING PLUG CABLE BOOT SEAL BOND AREAS

9.6.2 Anchoring the Connector and the Cable in the Boot - The minimum required engagement of both connector shell and cable is the principal determinant of the overall length of the cavity. This minimum engagement in the molded boot is a function of cable diameter and related connector shell diameter. The larger these diameters, the greater is the engagement required to withstand the increased stresses in the seal area. The recommended minimum cable engagement is the equivalent to two cable diameters. (See Figure 9-4). These are approximate figures, however, and will vary somewhat with the application and materials involved.

9.6.3 Cable Strain Relief - The other cavity length determining factor is the necessary distance to accomplish the transition between the normally larger connector shell diameter and the normally smaller cable diameter. This transition also serves the function of strain relief of the conductor bundle when the cable adjacent to the molded boot is flexed. This transition distance must be sufficiently long to accomplish this and varies with the molding material and cable stiffness. The transition distance increases with increased cable flexibility.

9.6.4 Encapsulation of the Connector Prepot Area - The overall space envelope of the mold cavity is further defined by the need to encapsulate any prepot of the conductors adjacent to the connector shell. The configuration of the prepotted area is normally cylindrical and requires a simple mold into which the potting material is poured. The cavity of this mold should be no larger than required to encapsulate the conductor bundle with a good interstice fill; it normally includes a short end of the jacketed cable. (See Figure 9-2). If the recommended cable and connector designs are used, then the conductor insulation should not be removed in the prepot area.

9.6.5 Minimum Boot Thickness - The cavity must provide for a nominal molded material thickness over the connector shell. This thickness varies with stress requirements and material used. Normal thickness varies between 3/16 inch and 3/8 inch, depending on the connector size.

9.6.6 Straight or Right-Angle Cable Entry - For those applications where the cable is to be sealed at a 90^{o} angle to the connector shell, the mold cavity dimensions are developed in the same manner. The total length (both legs) is slightly greater in order to "house" the 90^{o} turn in the conductor bundle. The cavity should be designed to accommodate the conductor bundle "turn" after its exit from the end of the connector shell, as shown in Figure 9-5.

Modification of the connector shell by slotting it to allow the conductor bundle to exit through the side of the connector shell has resulted in a greatly reduced service life. Smaller bond areas introduced by this design may cause early failure of the elastomer-to-metal bond in an area directly below the conductor exit point, leading to subsequent flooding of the connector. Figure 9-6 shows the area where this typical bond failure occurs.

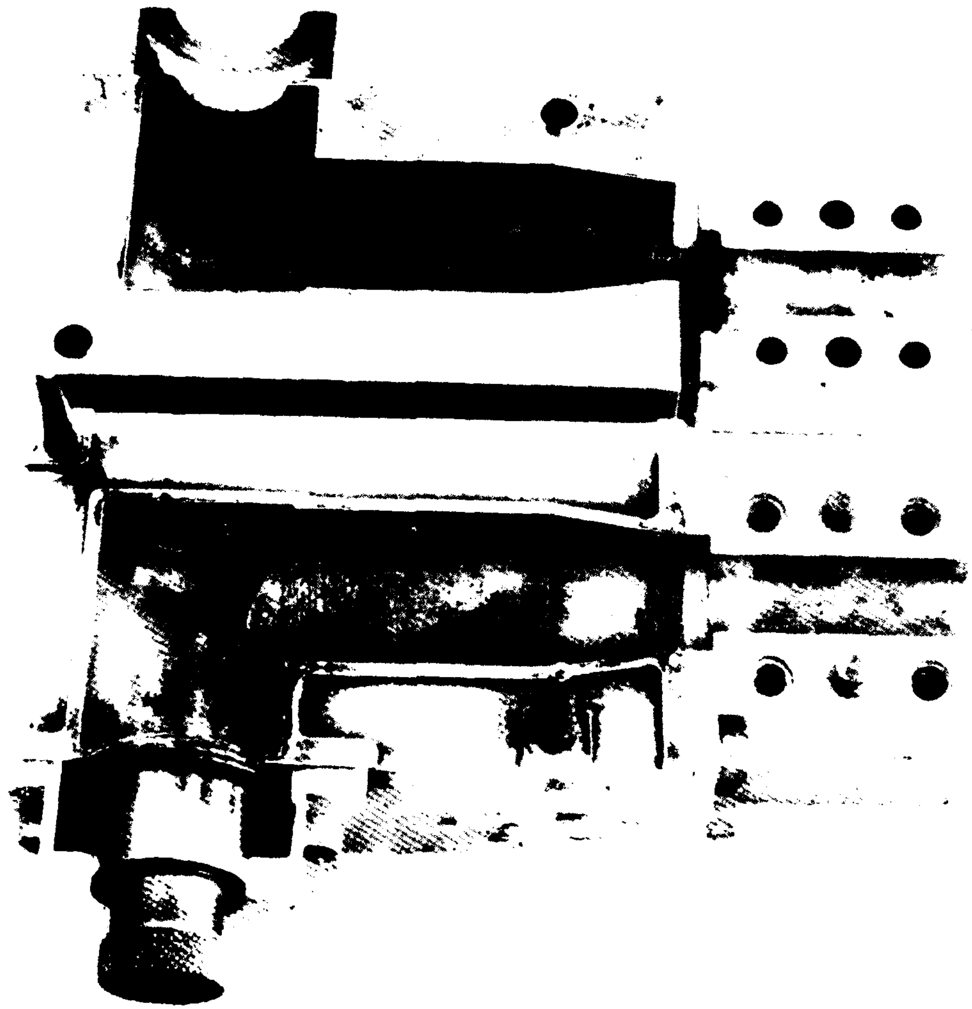


FIGURE 9-5 RIGHT-ANGLE PLUG MOLD DESIGN

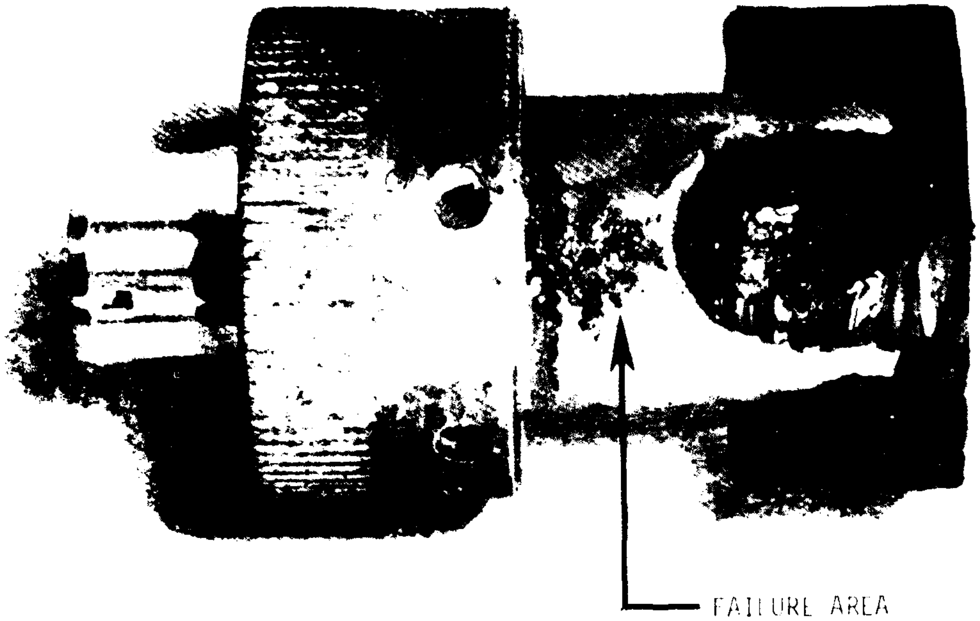


FIGURE 9-6 TYPICAL BOND FAILURE AREA IN RIGHT-ANGLE PLUG DESIGN WITH SLOTTED PLUG SHELL

9.6.7 Detail Mold Design Considerations - Other aspects of mold design that must be considered are:

(a) Locating and securing the connector in the mold,
(b) Locating and securing the cable in the mold,
(c) Molding material,
(d) Molding method, and
(e) Optimization of design for manufacture and flexibility of application.

9.6.7.1 *Locating and Securing the Connector* - A connector locating and securing device is required in all molds, and is particularly significant where the molding method requires the application of pressure. Connector components must be held firmly in place during the molding operation to prevent any relative movement that will stress the conductors or their termination. It is recommended that this be threaded into the connector coupling threads which are in position on the connector shell during the molding operation. (See Figure 9-7).

9.6.7.2 *Locating and Securing the Cable* - A cable retention device is essential to prevent cable movement and the resulting stressing of the electrical terminations during compression and transfer molding operations. Relatively high pressures can be exerted on the cable end, tending to force the cable out of the mold cavity. A split clamp that is completely detachable from the cavity portion of the mold is recommended. This permits a wide choice of clamp sizes to accommodate a range of cable sizes, thus providing the required snug fit. In addition, the clamp can be made up independently of mold closure;

9.6.7.2 (Continued)

this greatly reduces the possibility of a pinched or damaged cable jacket. The clamp should be split along the axis of the cable bore and have a minimum length of approximately three times the cable diameter. The clamp bore diameter should be approximately 0.010-0.015 inches less than the minimum specification diameter of the cable. Such variables as cable jacket thickness, cable roundness, construction density, and jacket material must be taken into consideration.

A cable clamp is also necessary, even where molding pressures are minimal, to center and maintain location of the cable during molding. Here, the bore diameter can be increased where no squeeze is necessary (see Figure 9-7) for the relative position of cable clamp and mold cavity).

9.6.7.3 *Molding Material and Techniques* - In most cases the choice of molding material must be made strictly on the basis of obtaining an adequate seal between molded boot and an existing cable jacket. The preferred approach would be to optimize this seal by proper selection of both cable jacket material and molding material. In addition, the molding method, and indirectly the molding material, is dependent on the environment in which the work must be accomplished. Lack of space, portable equipment, and adequate quality controls preclude the "in place" use of the more sophisticated molding techniques on board the vehicle. The quality of simple shipboard potting operations can suffer because of poor heat distribution or temperature control in the curing process.

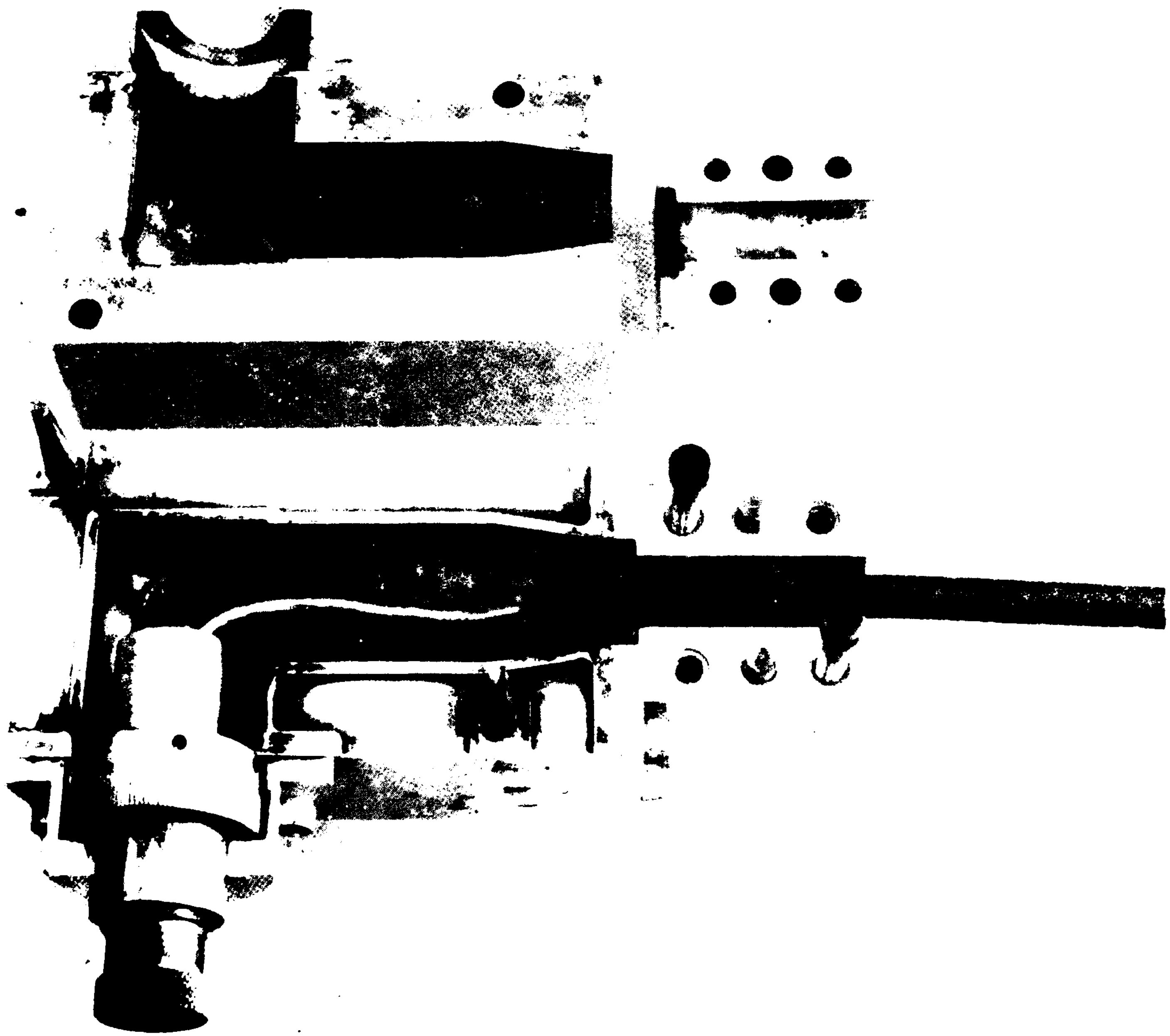


FIGURE 9-7 TYPICAL MOLD ASSEMBLY SHOWING LOCATION OF CONNECTOR SECURING DEVICE AND CABLE CLAMP

9.6.7.3 (Continued)

Wherever possible, the molding operation should be accomplished in the shop where the proper equipment can be made available and adequate quality control procedures implemented. Those instances where molding is done on the vehicle should be limited to repair work on installed harnesses or simple splices at the time of installation.

The nature of the material being molded influences mold design in the following areas:

(a) Fill and venting points,
(b) Mold closure,
(c) Mold seals,
(d) Flash relief areas,
(e) Transition angles.

Generally speaking, the materials that have good fill and leveling characteristics at room temperature, such as polyurethane, require little special design treatment. Adequately sized and properly located sprues are essential for a void-free fill. The principal vent should be enlarged at its outermost extremity as a reservoir of material to replace entrapped air as it is displaced. Provision must be made to fill the cavity from the bottom with the mold oriented so that the rising material level does not encounter cul-de-sacs where air will be entrapped. Polyurethane will flow into clearances as small as .002 inch; sealing gaskets must be provided around the connector shell, which is located at the bottom of the mold. Venting sprues are normally located at the cable end. Mating surfaces of the mold must be flat and smooth

9.6.7.3 (Continued)

and externally sealed with RTV silicone, as required, after assembly. No flash relief areas should be provided in a polyurethane mold, and transition angles can be smaller than in a similar mold for neoprene. All fill points should be threaded to permit insertion of a threaded plug after fill. Locating pins, located in one half of the mold, should be tapered for a short distancc to facilitate mating with holes in the other mold half. Mold halves can be held together with clamps or cap screws which engage threaded inserts pressed into the mold body; the latter is recommended. (See Figure 9-8.)

Neoprene molding of the cable sealing boot is accomplished by one of two methods or a combination of both, the two molding methods normally associated with neoprene being compression and transfer procedures. The compression molding technique involves wrapping the molded area with an unvulcanized rubber which is sheeted out and cut in strips for application. Good fill of the mold cavity is dependent on a dense wrap which approximates the mold cavity configuration; excess rubber moves into the flash relief area with closure of mold halves. The mold halves are brought between heated platens with a suitable ram pressure. The key to a satisfactory molded part lies in closing the mold at the proper time and temperature. This brief description of the process points out design features that must be incorporated in the mold. (See Figure 9-9). They include the following:

(a) A rugged mold with long taper locating pins that will tolerate considerable misalignment in the early stages of mold closure.

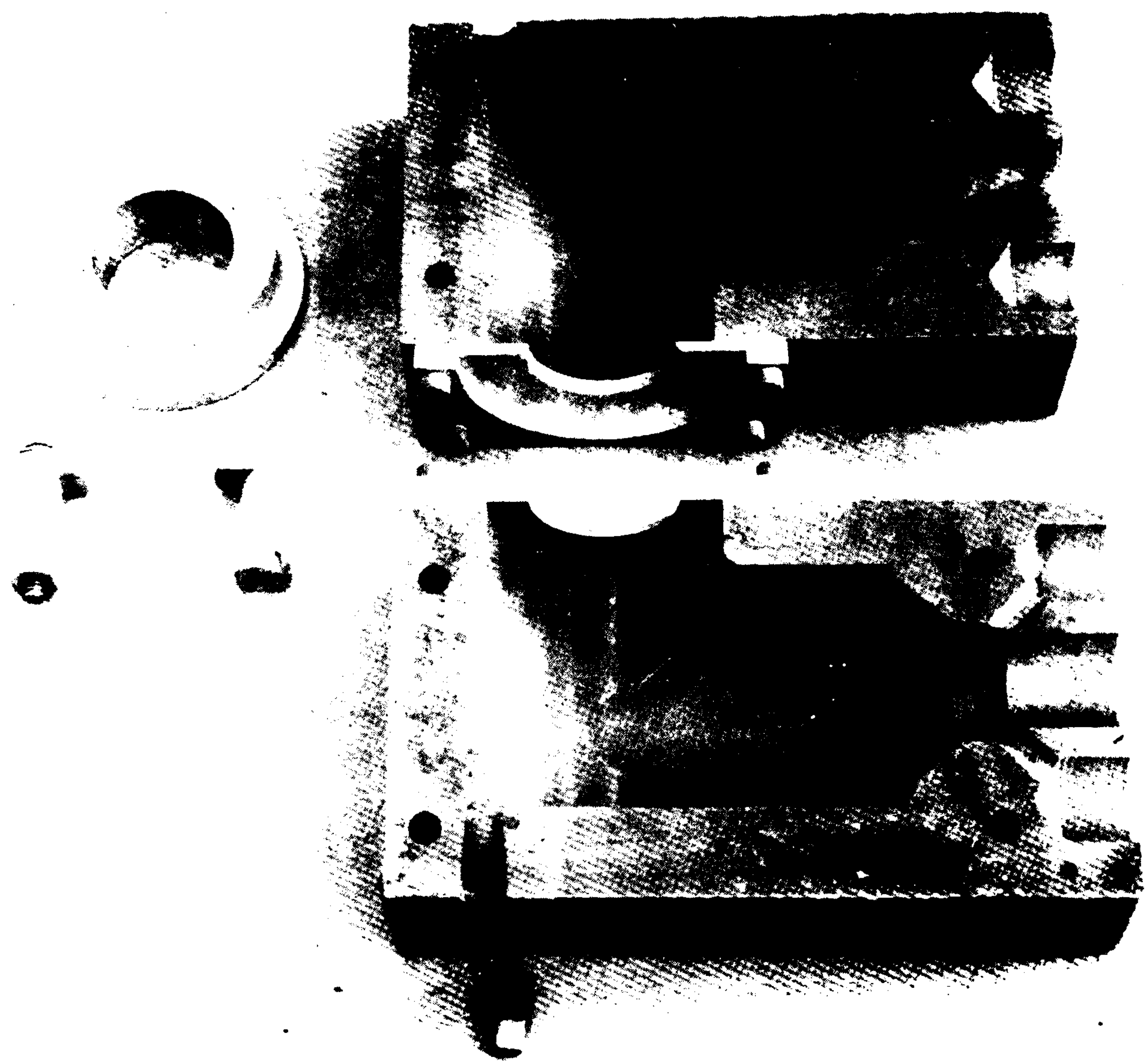


FIGURE 9-8 TYPICAL POLYURETHANE MOLD ASSEMBLY

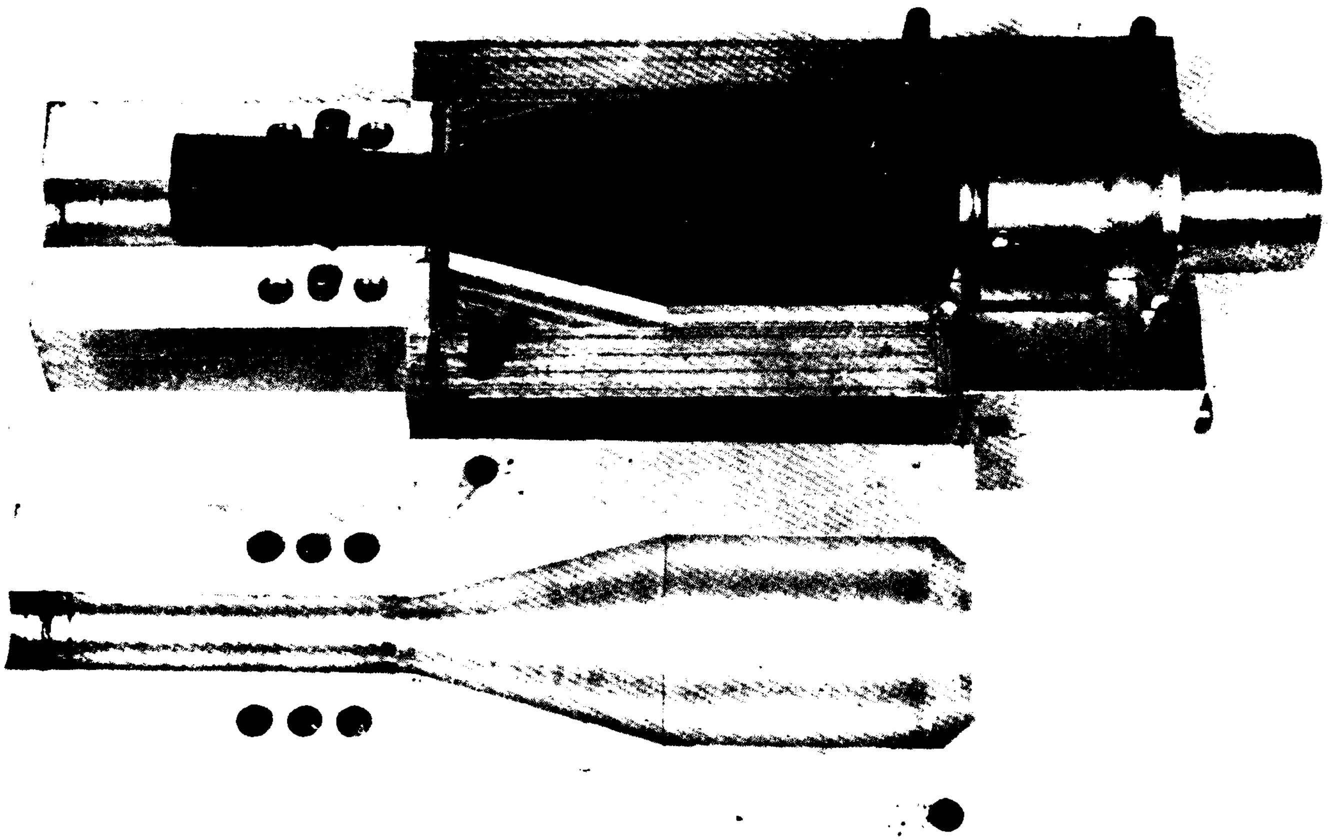


FIGURE 9-9   TYPICAL NEOPRENE MOLD ASSEMBLY

9.6.7.3 (Continued)

(b) Good heat transfer characteristics.

(c) A thermometer well for accurate determination of molding temperatures.

(d) Flat and parallel mold surfaces.

(e) A 1/16" deep flash relief area in half of the mold (same half as locating pins).

(f) A connector shell retention device which threads into the connector coupling mechanism and houses the mating end of the connector. An adjustable stop within the device is necessary to prevent the contact insulator from being extruded by molding pressures.

(g) A split cable clamp sized to provide the necessary retention to prevent cable extrusion with molding pressures. This is normally coupled by socket head cap screws which engage threaded inserts. Locating pins are necessary for proper alignment of the two clamp halves.

(h) All edges of the clamp bore must have a slight radius to prevent the cable jacket from being pinched as the clamp is closed.

(i) Jacking screws must be provided opposite all locating pins to open the mold after the molding operation.

Large production runs of neoprene cable boot molding are best accomplished by transfer molding, provided cable and conductor movement in the mold can be controlled. For consistent results, accurate temperature control and production-type presses are required.

9.6.7.3 (Continued)

In this operation, the unvulcanized rubber is fed into a pot and, when sufficiently softened by heat, is forced by a piston through sprues into the already assembled mold. Optimal location of fill and venting points is essential. In many cases, these have to be located by trial and error in order to prevent migration or stressing of conductors. In some instances, it is advantageous to use a combination pre-wrap, as for compression molding, and transfer the remaining rubber into the cavity. This procedure could be useful where the molded configuration does not compression-mold well due to its shape or size.

Transfer molding of polyethylene cable boots (on polyethylene cable) requires a very specialized type of connector surface preparation and has not seen wide application in the fabrication of underwater harnesses in the United States. Molding material used must have a melt index very close to that of the cable jacket for a good seal. Transfer time is limited to the time that the material can be kept molten. In order to better control the transfer operation, transparent molds of acrylic resin have been used. All other design features of the mold are quite similar to the transfer mold described for neoprene.

9.6.7.4 ***Optimization of Mold Design for Manufacture*** - Certain details of design can significantly reduce the cost of manufacture and add to the adaptability of the mold. These design details include the:

(a) Mold material choice,
(b) Removable insert for the conical portion of the cavity, and
(c) Detachable cable clamps.

9.6.7.4 (Continued)

Molding operations requiring the application of pressure and rapid heat transfer to the mold cavity, such as compression molding, are better accomplished in a mold machined from aluminum or other metal. In the case of polyurethane "casting" operation, however, a metal-filled epoxy can be used to advantage as the mold material. A properly sealed wood model of the cavity is positioned in a box and the epoxy poured around it. The parting line is established along the longitudinal axis of the model. This material is readily machinable and adequately strong and hard, with a very tolerable coefficient of thermal expansion. An aluminum-filled epoxy is recommended; aluminum locating pins are inserted after the epoxy is cured. The material is readily available and reduces mold manufacture to a minimum.

In those cases where the mold cavity is milled out of aluminum, it is advantageous to have a separate detachable insert for the conical transition area between plug shell and cable. This can be turned from round bar, thus simplifying the machining operation. This design has the added advantage of making the plug shell cavity adaptable to several cable sizes.

Cable clamps should not be an integral part of the mold. Separate cable clamp assemblies attached by cap screws make it possible for a single mold to be adapted to several cable sizes.

9.7 Cable Harness Wiring and Molding Considerations

The following wiring and molding steps are of primary importance in fabricating a harness assembly.

9.7.1 Cable Inspection - A thorough inspection of all cable prior to harness fabrication is essential in order to ensure watertight integrity of the jacket and all-around electrical integrity. Any harness fabrication procedure should include inspection and handling guidelines as part of in-process quality control. Areas of principal interest include:

(a) Verification of cable type specified,

(b) Visual inspection of cable jacket for nicks, cuts, abrasions, or manufacturing defects that could affect the watertight integrity or service life of the completed harness.

(c) Electrical requirements including insulation resistance and dielectric withstanding voltage and continuity.

(d) Outside diameter of the cable (for mold fit).

(e) Proper handling and packaging to insure that the cable remains in the inspected condition.

9.7.2 Connector Inspection - A careful inspection of all connector components prior to harness fabrication is also essential and should include the following checks. Harness fabrication procedures should also include inspection and handling guidelines as part of in-process quality control.

9.7.2 (Continued)

(a) Verification of the connector specified.
(b) Visual inspection of the connector components for burrs, scratches, nicks, or machined grooves in the O-ring seal areas.
(c) Visual inspection of connector insulators to ensure that contact positions are properly marked.
(d) Inspection of contacts for their ability to mate with their respective size test pins and to accommodate their specified mating conductor size.
(e) Inspection of connectors for proper polarizing key-keyway locations.
(f) Dimensional inspection of pertinent plug-receptacle mating dimensions, as well as dimensions which will allow proper assembly in the mold cavity.
(g) See 9.9.1.(c).

9.7.3 <u>Safety Precautions</u> - Adherence to the following safety precautions when using solvents in mold preparation is most important:

(a) Do not smoke or use an open flame in working area. Methyl ethyl ketone (MEK) is highly flammable.
(b) Be sure the working area is well ventilated to prevent excessive exposure to the toxic vapors.
(c) Avoid excessive contact with solvents, primers and compounds. If necessary, wear rubber or plastic gloves. Splashes or spills should be washed from the skin immediately with soap and water.

9.7.3 (Continued)

(d) Use safety cans for the transfer and storage of solvents. The solvents may be transferred to smaller safety cans or 1-pint polyethylene wash bottles, for ease of handling. During use, however, do not pour solvents into open containers.

(e) Do not leave solvent-saturated rags and paper wipes in the working area. Place them in safety waste cans immediately after use.

9.7.3.1 *Safety Precautions when Using Epoxies* - There are two components which make up most epoxy resin systems:

(a) The resin (with or without filler); sometimes labeled "A" component.

(b) The hardener in a fluid or paste-like consistency; sometimes labeled "B" component.

9.7.3.1.1 *Resin* - There are several types of epoxy resins; some are safe to handle, others are not safe and should not contact the skin. Some individuals may show allergic tendencies with these materials and should follow precautionary measures noted below. Some resins may have diluents added to facilitate their processing, and these diluents may be harmful or noxious in odor. In either case, follow precautionary measures below. (par. 9.7.3.1.3)

9.7.3.1.2 *Hardener* - Hardeners, or cure agents as they are called, differ in their ability to cure resins, as well as their tendency to cause skin irritation or dermatitis. Most room temperature-set hardeners are based on polyamines (such as diethylene triamine). If proper precautions are followed, hardeners can usually be handled without difficulty. Safety hardeners are now available, although infrequently an individual shows an allergic reaction to these. This usually appears after repeated or prolonged contact with the hardener. The elevated temperature curing agents are generally aromatic amine or acid anhydrides. Most aromatic amines will tend to discolor the skin. Follow the precautions noted below (taken from Reference 9-6).

Since epoxy formulations have varying degrees of hazard, the Society of the Plastics Industry (SPI) has produced a guide for classification of products for the benefit of the industrial user. With this knowledge, the user should be able to safely handle these products. The hazard category is given in terms of degrees as follows:

Class 1	-	Practically non-irritating
Class 2	-	Mildly irritating
Class 3	-	Moderately irritating
Class 4	-	Strong sensitizer
Class 5	-	Extremely irritating
Class 6	-	Suspected carcinogen in animals

9.7.3.1.3 *Precautionary Measures* - These measures are taken directly from Reference 9-1.

(a) Mix and apply materials in well ventilated areas, preferably with a forced air draft to carry away fumes. Ovens used to heat-cure epoxies should be safely ventilated to outside areas.

9.7.3.1.3 (Continued)

(b) Avoid contact of materials with the skin. Use rubber gloves, preferably with a cloth liner, to absorb perspiration.

(c) Wear Protective clothing when material contact is anticipated. Long rubber or vinyl coated gloves with cloth interiors are suggested, and goggles or eye shields to protect the eyes if splashing of the hardener occurs.

(d) Observe good personal hygiene. Avoid contaminating clothing or the inside of gloves. Use soap and warm water at frequent intervals to clean hands and do not use strong cleaning solvents such as acetone or methyl ethyl ketone which dissolve protective oils from the skin. If cleaning of epoxy resin from clothing is necessary, a 50:50 mixture of denatured alcohol and toluene is suggested. Use denatured alcohol only to clean hands or skin.

(e) Follow good housekeeping rules and do not leave deposits of epoxy resins or hardeners on work areas, bottles, door-knobs, etc. Wipe off immediately with paper towels or rags. Use disposable mixing containers and throw-aways wherever possible.

(f) Some individuals find that the application of barrier creams to hands and face is desirable before beginning work. (West Disinfectant 411 and Kerodex are among creams found satisfactory. Your physician can recommend others). Re-apply barrier creams after washing hands.

9.7.3.1.3 (Continued)

(g) Should skin afflictions or irritations appear, qualified medical help must be obtained. The physician should be informed that skin irritation could have been caused by aliphatic polyamines. In uncomplicated cases, the skin irritations will disappear quickly; in serious cases, it may require a few days to clear. In general, irritations may reappear when work is resumed, unless adequate protection is followed. Persons who are known to be particularly susceptible should be immediately transferred to work which entails no risk whatsoever of dermatitis.

(h) These materials are for professional and industrial use only and should be kept away from children.

(i) If you have any doubts or skin irritations, see your doctor for professional guidance.

(j) Do not smoke, eat or drink in areas where mixing is taking place.

9.7.3.2 *Safety Precautions when Using Urethanes** - The general precautions applicable to handling the components of an epoxy system are applicable to the handling of urethanes. Please read and put into practice the recommendations shown in Section 9.9.3.1.

Urethane reaction materials which involve isocyanates are potentially hazardous in both the liquid and vapor states. They may act as irritants to the skin and mucous membranes, especially the eyes and upper respiratory regions, where in some allergic individuals asthma-like attacks may occur. Concentrations below the odor threshold may affect sensitive persons who are subject to hayfever and asthma. If you suspect problems or show skin sensitivity, see your doctor for professional guidance.

*From Reference 9-6.

9.7.3.2 (Continued)

Skin exposure should be avoided, and accidental spillate must be thoroughly removed by washing with soap and water. Eyes should be irrigated with large quantities of water and a physician consulted. To avoid hazards when working continually in a urethane atmosphere, protective clothing, eye shields, and gloves are suggested, as well as outside-air-supplied respirators where vapor concentrations are high.

There are certain types of resins and hardeners which are considered more toxic than others. In keeping with industry requirements, a special precautionary label is affixed to the containers. The language of the label is as follows:

> "DANGER - PROLONGED OR REPEATED CONTACT OF LIQUID OF BREATHING OF VAPORS OR MISTS MAY CAUSE DELAYED AND SERIOUS INJURY. DO NOT GET ON SKIN OR CLOTHING. AVOID INHALATION OF VAPOR OR MISTS. IN CASE OF SKIN CONTACT, WASH THOROUGHLY WITH SOAP AND WATER. REMOVE CONTAMINATED CLOTHING AND WASH THOROUGHLY BEFORE REUSE".

9.7.4 Preparing the Cable Ends - The wiring and molding manual used by the technician must include sketches of proper cutting lengths for each type cable to be terminated. The cable jacket and binder tapes should be removed with a sharp knife or razor-bladed tool. Care must be taken not to cut the conductor or shield insulations. Elastomeric cable fillers should be removed at this time. The insulation direct'y over the conductors should be removed with a thermal stripping tool to prevent nicking the conductor strands. The individual strands of the conductors must be cleaned to remove the strand sealant. Care must be taken to have the conductor and shield

9.7.4 (Continued)

lengths prepared as specified on the sketch in the manual so as not to impose undue stresses on any one conductor when terminating it to the contacts.

9.7.5 Connecting the Conductors and Shields to the Contacts - Mechanical crimping methods are recommended, where possible, to mechanically and electrically connect the contacts to the conductors and shields. The military and industry have found this method to be most reliable in service and more easily quality controlled than other methods used previously. Such methods as wire wrapping are equally reliable but are not suited to these designs as they occupy more space than is available. Conductor crimping tools fabricated in accordance with MIL-C-22520 should be used to crimp signal and control cable wires. These tools are detailed on military specification sheets of MIL-C-22520. Reference 9-7 is an excellent source for general crimping information. From the techniques described in Reference 9-8, it is seen that inner and outer crimp rings in conjunction with a pigtail lead can be used to terminate shields. Also, a one-piece insulated Burndy Corporation UNIRING has been widely used. The RAYCHEM Corporation Solder Sleeve is another termination method which recently has found wide use. One advantage of the solder sleeve is that the design conserves space in back of the connector; space availability in this area is at a minimum. All three methods are acceptable; their use is primarily dependent on which one the terminating activity is most comfortable using.

9.7.5 (Continued)

In cases where crimped contacts cannot be used, the wire can be connected to the contacts with solder. A resin core solder (60 percent tin, 39.75 percent lead, 0.25 percent antimony) in accordance with Federal Specification QQ-S-571 should be used. An electric soldering iron with a rating of 60 to 100 watts should be used for the smaller contacts. The iron should be maintained at $600^{o}F$. The larger size power cables should make use of a 250-300 watt soldering iron. MIL-STD-440, NAVSHIPS 250-706-2, MIL-STD-454 Requirement 5, MIL-S-6872 and MIL-S-45743 all relate to proper soldering procedures and their quality control.

9.7.6 <u>Cable Jacket Preparation</u> - Cable jacket preparation in the area to be molded varies somewhat depending on the jacket material. Generally speaking, the surface must be free of all contaminants such as jacket extruding lubricants and accumulated oil. The cable should be wiped with the appropriate solvent (see section 10) prior to and following cable abrasion in the area to be bonded. In addition, a uniform abrasion of the surface is recommended. This can be accomplished with a 60-70 mesh abrasive cloth. All resulting dust should be removed. Primers, where required, should be applied uniformly and the primed surface should be protected from contamination until molding. A plastic bag placed over the prepared cable end and taped tightly to the jacket beyond the prepared area provides good protection.

9.7.7 Plug Shell Preparation - That area of the connector shell that is included in the molded seal to the cable requires special surface preparation. This preparation includes solvent cleaning, abrasive blasting, and priming. Prepared surfaces must be kept meticulously clean until the molding operation is accomplished. Solvent cleaning is best accomplished in the vapor phase; trichlorethylene is recommended as a solvent. Grit blasting should be accomplished in an oil-free air stream. The grit used should be in accordance with MIL-S-22262, Class 2 and should produce a sharp uniform anchor pattern having a profile depth from peak to valley of 2 to 4 mils. The part should be solvent vapor cleaned again after grit blasting and the surface protected until primed and molded. Allowable intervals between the above operations should be held to a minimum (4 hours is suggested) to eliminate possible contamination of parts. Primer applications should follow the manufacturer's instructions.

9.7.8 Encapsulation of the Prepot Area - Conductor terminations made within the connector shell should be potted for several reasons. These include void filling to exclude moisture; support of conductors and their termination against stresses and possible movement during molding of the cable boot; and, in the area of their termination, support of conductors against end forces that can cause column failure and electrical discontinuity with cycling pressure. All three functions are essential for a satisfactory service life. In order to accomplish the latter function of column support, the potting material and conductor insulation in the critical area must have a high bulk modulus. There must be no voids or areas of easily compressed material into which the conductor stranding can move when compression loaded

9.7.8 (Continued)

by hydrostatic pressure. This requires that conductor rubber insulating materials be removed and replaced by a shrink sleeve. A high density material such as "KYNAR"* is recommended.

The prepotting will not function as a secondary barrier to the entry of water into the contact area. Water leaking past a defective cable boot will normally find its way to electrically critical areas in back of the plug via a very slight separation between potting material and plug shell. This separation results from a material shrinkage which cannot be satisfactorily controlled.

The potting material should have a high bulk modulus in the cured state which is accomplished by filling with a material such as short milled glass fiber. The amount of filling is limited by the requirement for a reasonably low pot viscosity to ensure a void-free fill.

9.7.9 Molding the Cable Boot - At this point in the fabrication sequence, the choice of molding material and related molds has been made. Each set of materials and molding processes requires a stepwise procedure. This procedure should cover such factors as material and mold preparation, mold packing, venting, and cable retention. The three variables of time, temperature, and pressure, must be defined. Precautions and means of avoiding air entrapment or voids in the completed boot must be covered. The methods to be used for mold opening and part removal should be included to ensure a quality product. A method of molding-material flash removal and allowable repair methods must also be covered.

---

* Semi-rigid, high temperature, irradiated polyvinylidene fluoride tubing.

9.7.10 Testing the Completed Cable Harness - Each completed harness should be examined and tested in accordance with recommendations for quality assurance test outlined in Section 12 .

9.7.11 Packaging the Cable Harness Prior to Installation - The completed harness must be protected against mechanical damage or electrical contamination. The following steps should be taken to assure this protection:

(a) Provide all receptacles and plugs with screw-on protective caps having environmental seals. These can be of a molded plastic or easily processed metal with reasonably good impact strength.

(b) Cables should be coiled with a larger than minimum allowable bend radius, and the coil tied at intervals. All connectorized ends should be tied to the coiled cable close to the connector.

(c) The coiled harness should be placed in a bag as protection against jacket damage from abrasion or solvents.

9.8 Cable Harness Specification

A general specification should be prepared and published covering the majority of pressure-proof cable harnesses. This specification, similar in format to MIL-C-915 specification sheets, should include the following sections:

1. Scope
2. Applicable Documents
3. Requirements
   - 3.1 Materials
     - Plug
     - Receptacle
     - Cable
     - Potting Compounds
   - 3.2 Design and Construction
     - Reference to Proposed Wiring and Molding Manual
   - 3.3 Harness Identification Procedure
   - 3.4 Harness Performance Requirements
     - Production Test Requirements
     - First Article Test Requirements
4. Quality Assurance Provisions
   - 4.1 First Article and Production Test Methods
5. Preparation for Delivery
   - 5.1 Preservation and packaging
   - 5.2 Packing
   - 5.3 Marking
6. Ordering

Appendix - Reliability/Maintainability Requirements

9.8 (Continued)

1. Test Program
2. Test Results
3. Failure Reporting, Analysis, Corrective Action

A supplement to the proposed military specification should include specification sheets which detail each harness assembly. A typical sheet is shown in Figure 9-10. The sheet specifies the plug or receptacle and the cable used to fabricate a harness. The proper wiring schematic is also noted on this sheet or a separate sheet if space does not permit proper detailing of this information. A wiring schematic is necessary to delineate which contact or contacts carry the shield terminations.

It is felt that a quality underwater electrical harness assembly can only be achieved by following the proposed military specification procedure outlined as noted in this section of the Handbook.

MILITARY SPECIFICATION SHEET
CABLE HARNESS ASSEMBLY FOR
3 NO. 16 SIZE CONTACTS

THE COMPLETE REQUIREMENTS FOR PROCURING THE CABLE HARNESS ASSEMBLY DESCRIBED HEREIN SHALL CONSIST OF THIS DOCUMENT AND THE LATEST ISSUE OF MIL-C-XXXXX(SHIPS).

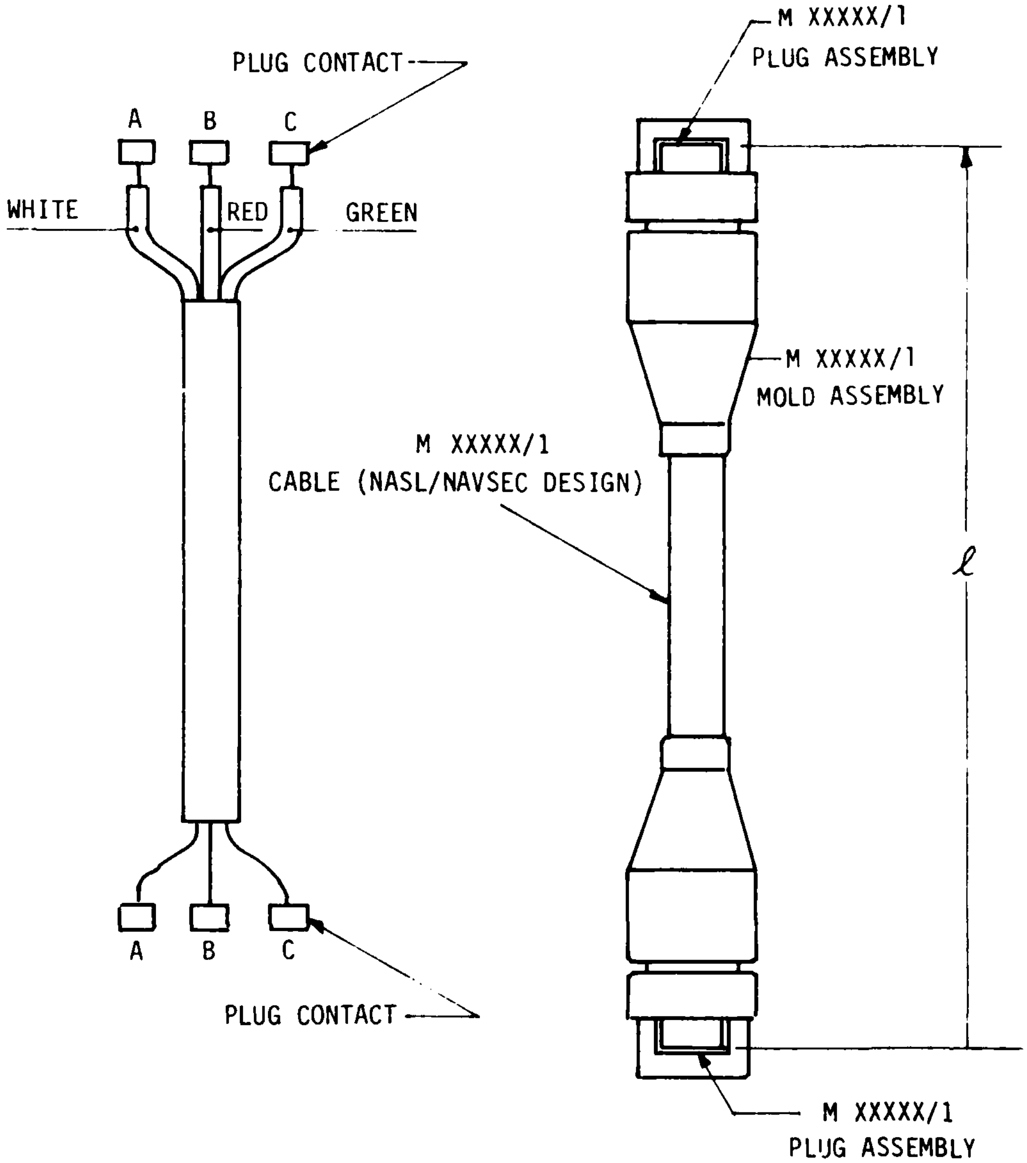


FIGURE 9-10 TYPICAL CABLE HARNESS SPECIFICATION SHEET

9.9 Armored Harness Termination Design

An armored cable harness is comprised of electrical conductors with cable strength members located inside the cable or external to the cable jacket. Various types of armored cables are depicted in Figures 9-11 and 9-12. These designs are well detailed in Reference 9-9. The termination design provides proper transfer of the cable load to the termination method. The cable strength members are usually comprised of strands of high tensile strength wire. In many cases, the wire is "plow steel" capable of a 240,000 psi breaking load.

9.9.1 <u>Armored Harness Termination Types</u> - Armored harness termination designs are determined by the cable construction and fall into three basic types: (1) central strength member, (2) external counter-wound strength member, and (3) external braided strength member.

Reference 9-10 is an excellent paper which discusses and depicts the various types of termination methods, which are as follows:

A. Central Strength Member

1. Swaged ball (Figure 9-13).
2. NICOPRESS swagged sleeve (Figure 9-14).
3. Potting in epoxy (Figure 9-15).

B. External Counterwound Armor

1. NICOPRESS swagged sleeve (Figure 9-16).
2. Potting in a tin-bismuth alloy (Figure 9-17).
3. Vise grip (Figure 9-18).
4. Amergraph cable grip (Figure 9-19).
5. Preformed Line Products (Figure 9-20).

9.9.1 (Continued)

C. External Braided Armor

1. Potting in epoxy (Figure 9-21).
2. Conical wedge (Figure 9-22).

The electrical connector can be placed within the mechanical termination or it can be disassociated from the termination by placing it off to the side. Figures 9-23 and 9-24 depict an integral strength member/electrical connector termination. Figure 9-25 shows a disassociated connector/strength member termination. Reference 9-10 notes that, where possible, it is preferably to keep the electrical connector termination separate from the mechanical terminations so that each can be designed to suit its specific function. The basic reason for this disassociation is the unnecessary complication of the electrical connector design due to difficulties in sealing the cable, as well as cable strain relief design at this juncture.

Much design work and testing by Government and private agencies has been accomplished in the armored cable termination area. References 9-11 through 9-14 are evidence of this work. Also, a number of companies have developed proprietary products which have found wide use in recent years. These are as follows:

1. NICOPRESS Sleeve
   National Telephone Co., Cleveland, OH.

2. DYNA-GRIP Dead Ends
   Preformed Line Products, Co., Cleveland, OH.

3. Amergraph Cable Grip
   United States Steel Corporation, NY, NY.

Finally, Table 9-6 lists the basic termination methods that can be considered in armor cable termination applications.

TABLE 9-6

Armored Electrical Cable Termination Methods *

Type	Description	Ease Of Assembly (Labor)
Brass Cable Grip	Vise grip	Unskilled Figure 9-13
NICOPRESS Sleeve	Swage	Semi-skilled Figure 9-14
Epoxy Potting	Chemical Bond	Skilled Figure 9-15
ASARCO-LO Potting	Sweat Solder	Skilled Figure 9-17
Preformed Line Products	Mechanical Ferrule	Semi-skilled Figure 9-20

* Taken from Reference 9-10.

Note: Strength members are darkened.

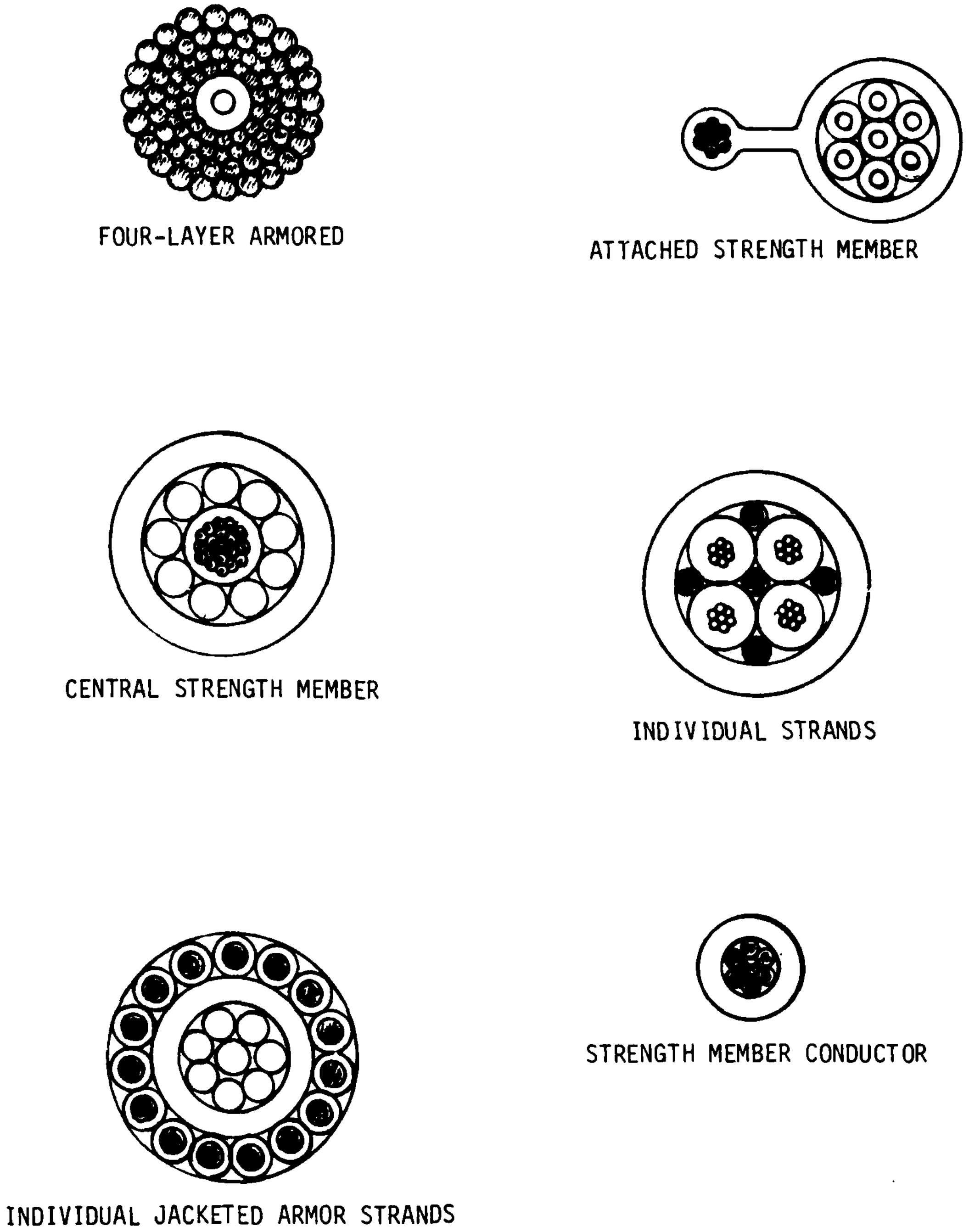


FIGURE 9-11 ARMORED CABLE DESIGNS

Note: Strength members are darkened.

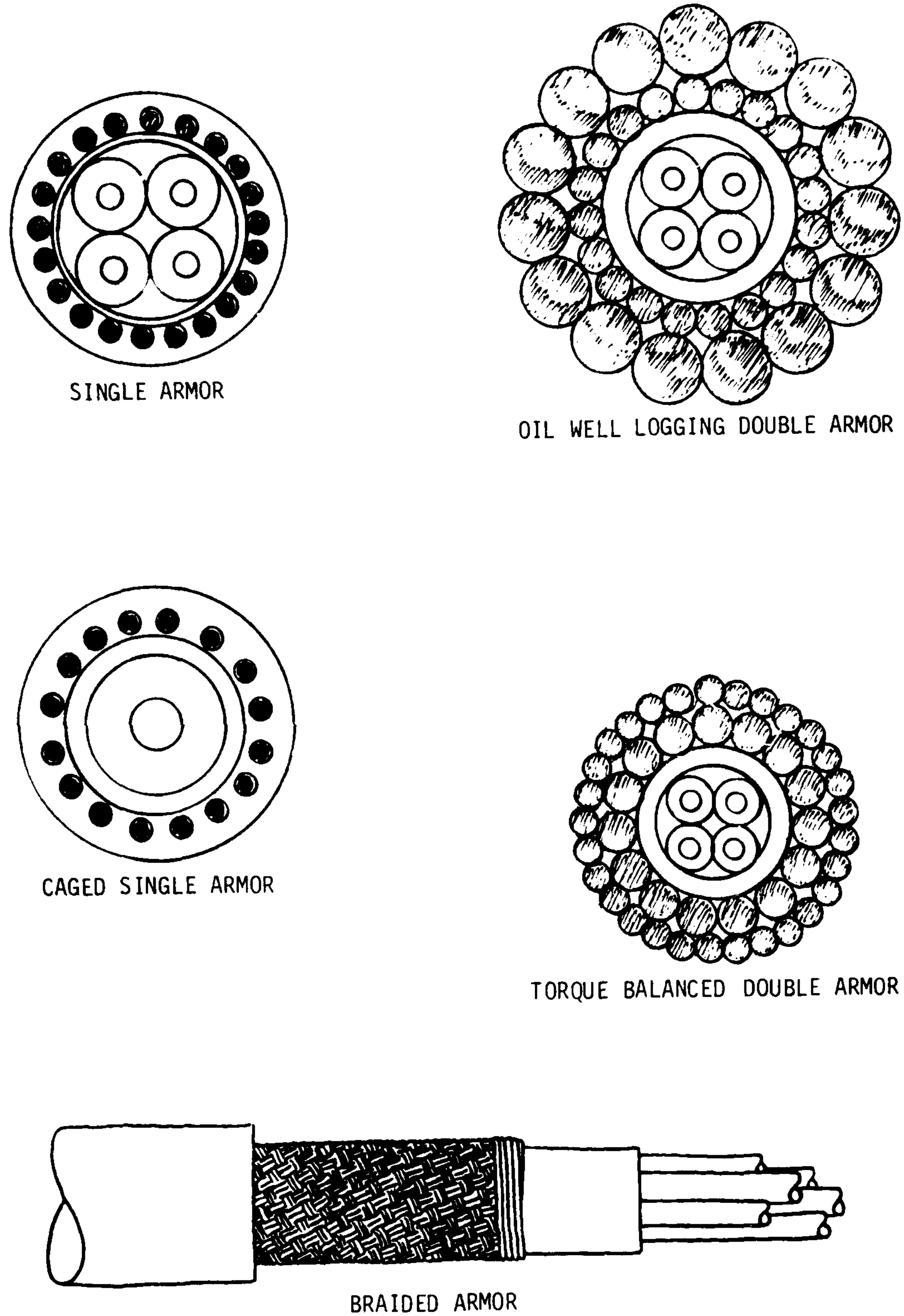


FIGURE 9-12 ARMORED CABLE DESIGNS

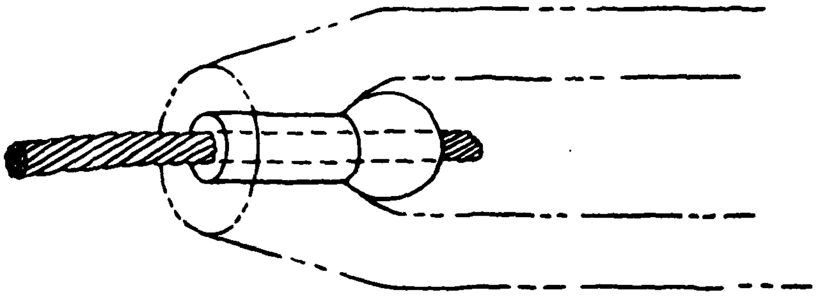


FIGURE 9-13

SWAGED BALL TERMINATION METHOD FOR CENTRAL STRENGTH MEMBER

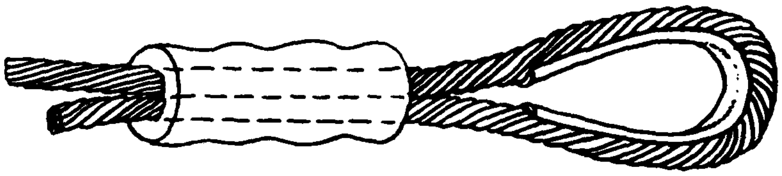


FIGURE 9-14

NICOPRESS SWAGED SLEEVE TERMINATION METHOD FOR CENTRAL STRENGTH MEMBER

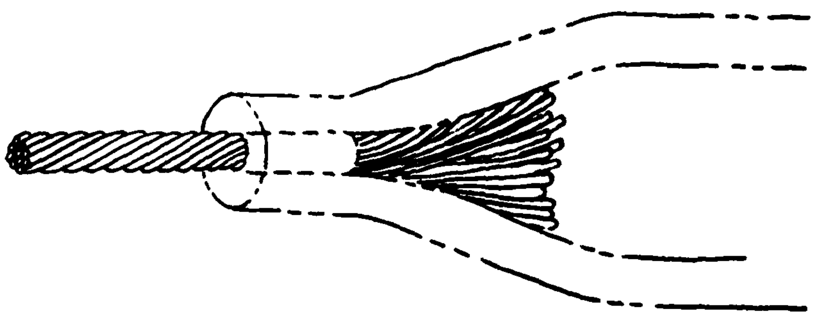


FIGURE 9-15

SOLDER CONE OR EPOXY POTTING TERMINATION METHOD FOR CENTRAL STRENGTH MEMBER

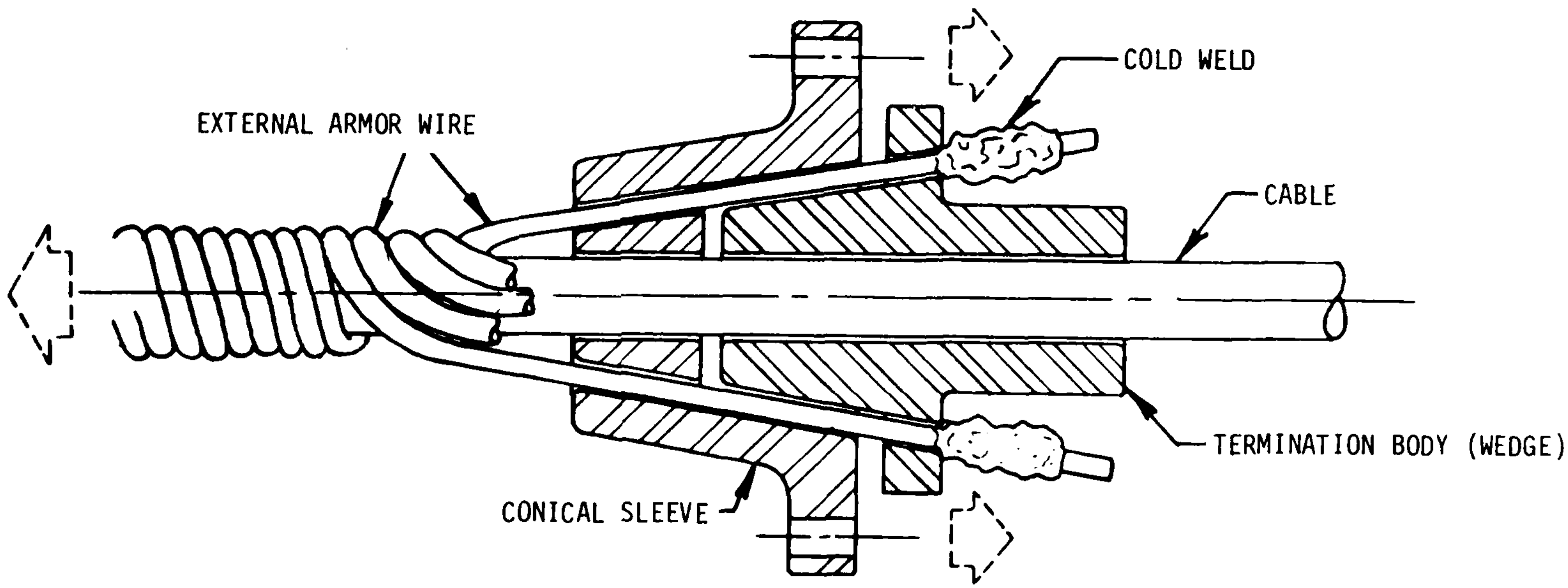


FIGURE 9-16 NICOPRESS SWAGED SLEEVE TERMINATION FOR EXTERNAL COUNTERWOUND STRENGTH MEMBER

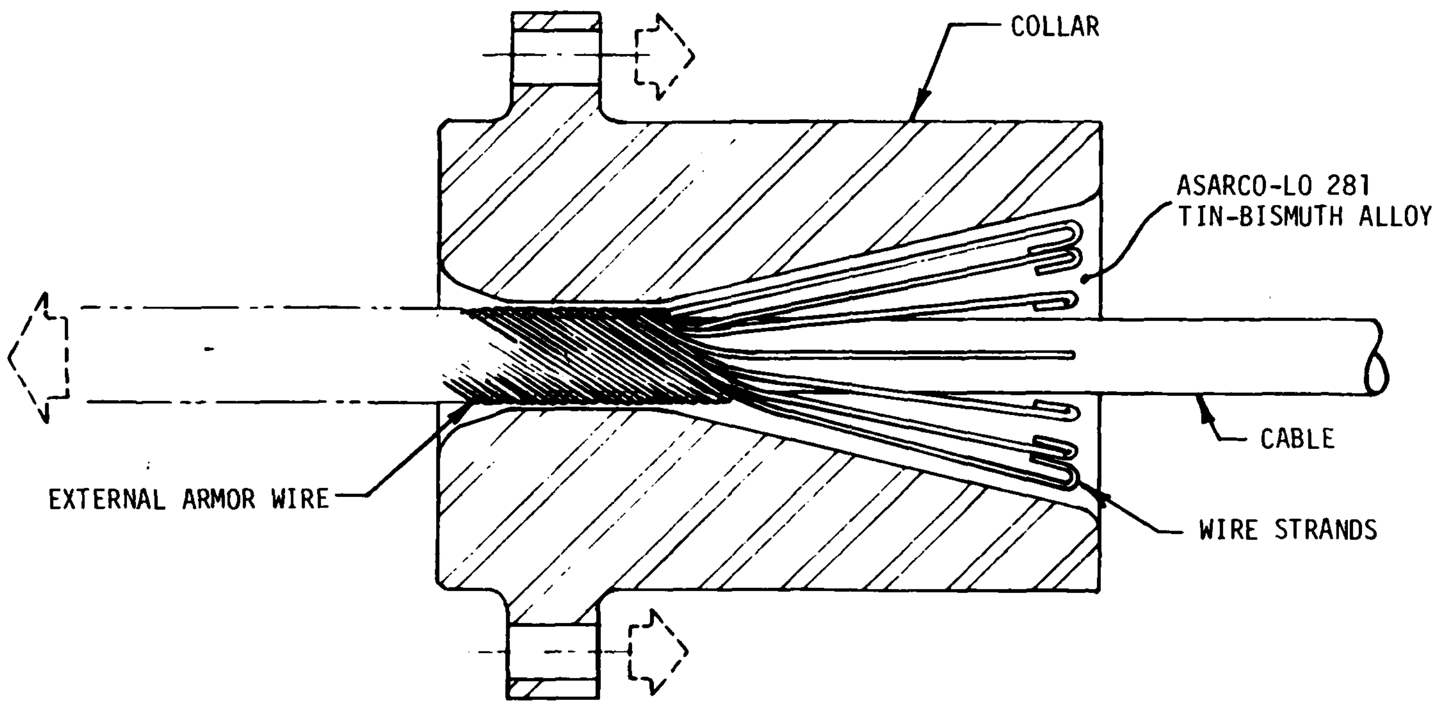


FIGURE 9-17 ASARCO TIN-BISMUTH ALLOY TERMINATION FOR EXTERNAL COUNTERWOUND STRENGTH MEMBER

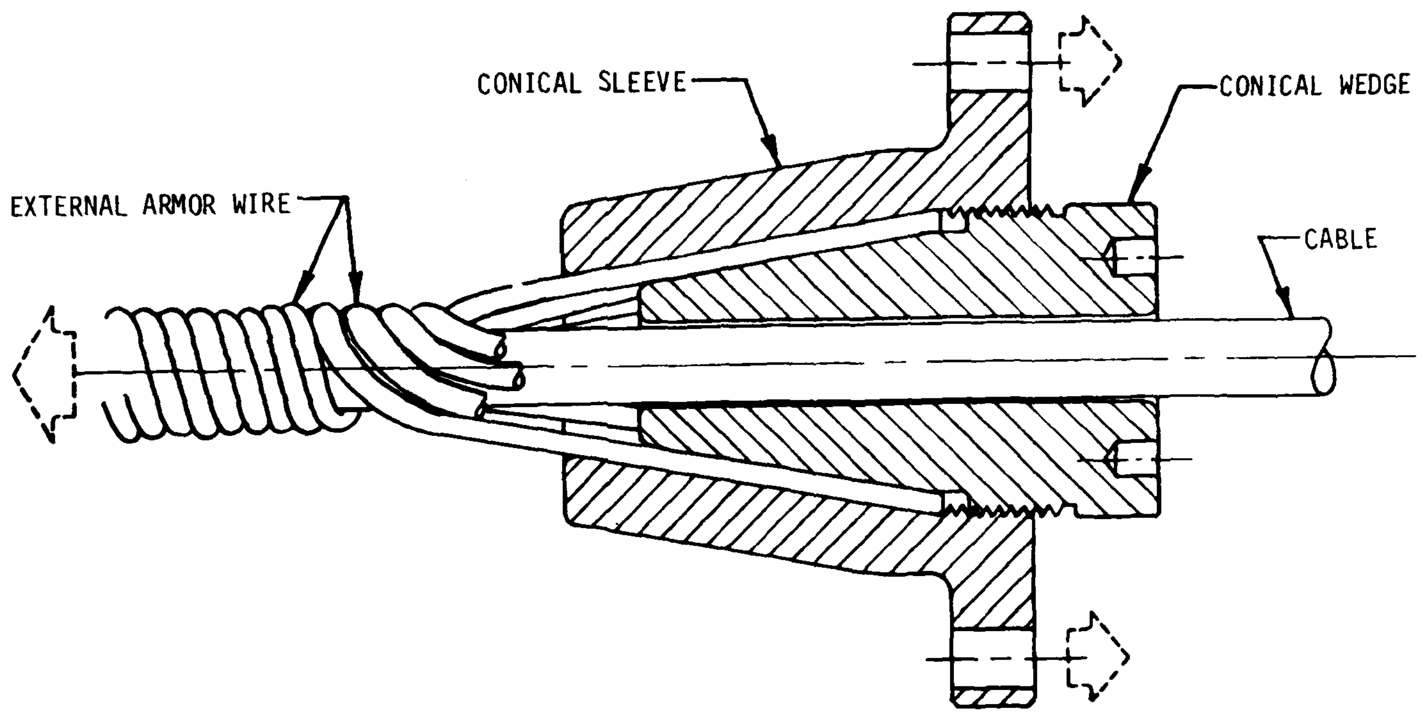


FIGURE 9-18 VISE GRIP TERMINATION METHOD FOR EXTERNAL COUNTERWOUND ARMOR

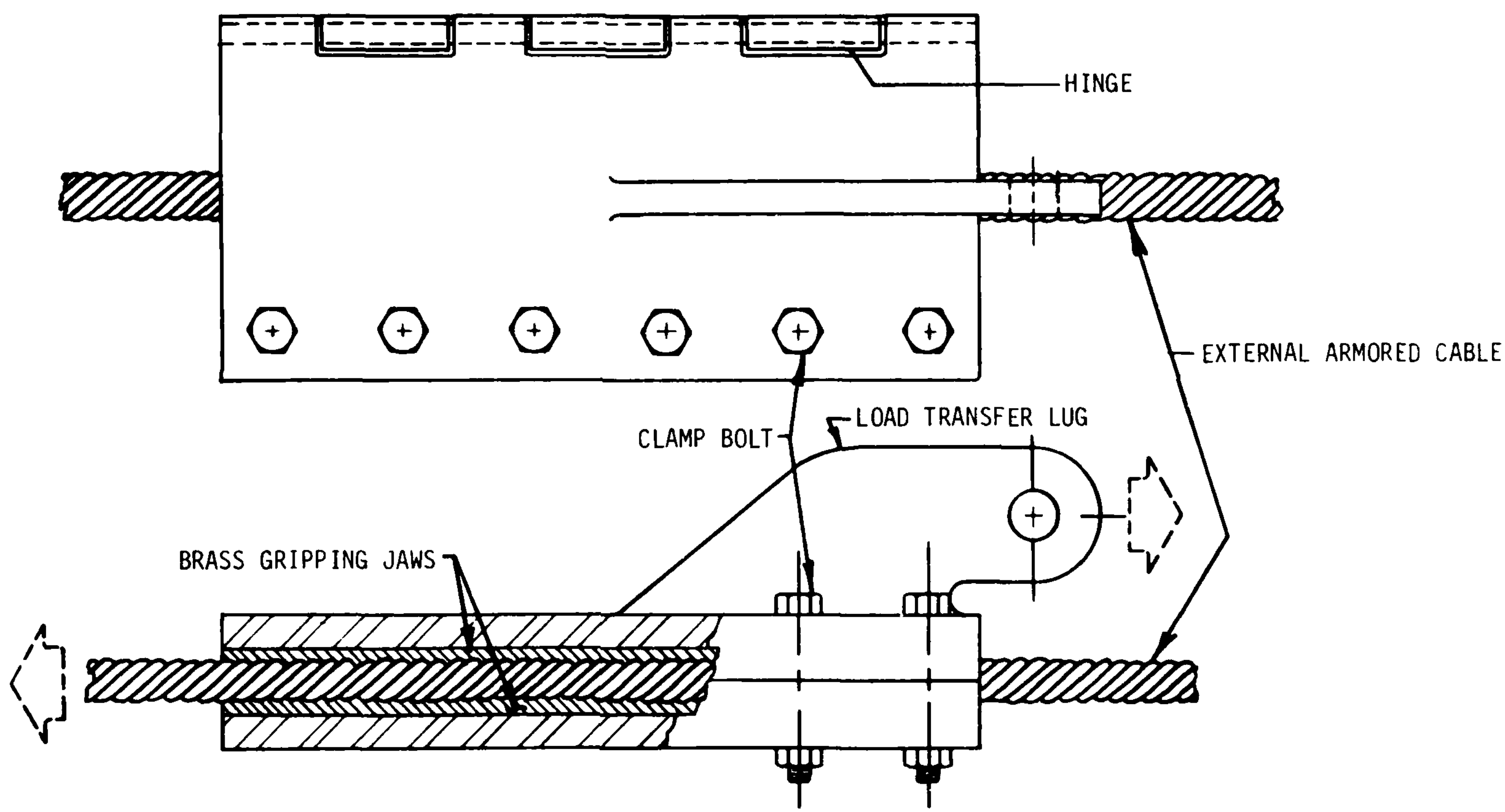


FIGURE 9-19 AMERGRAPH CABLE GRIP TERMINATION METHOD FOR EXTERNAL COUNTERWOUND ARMOR

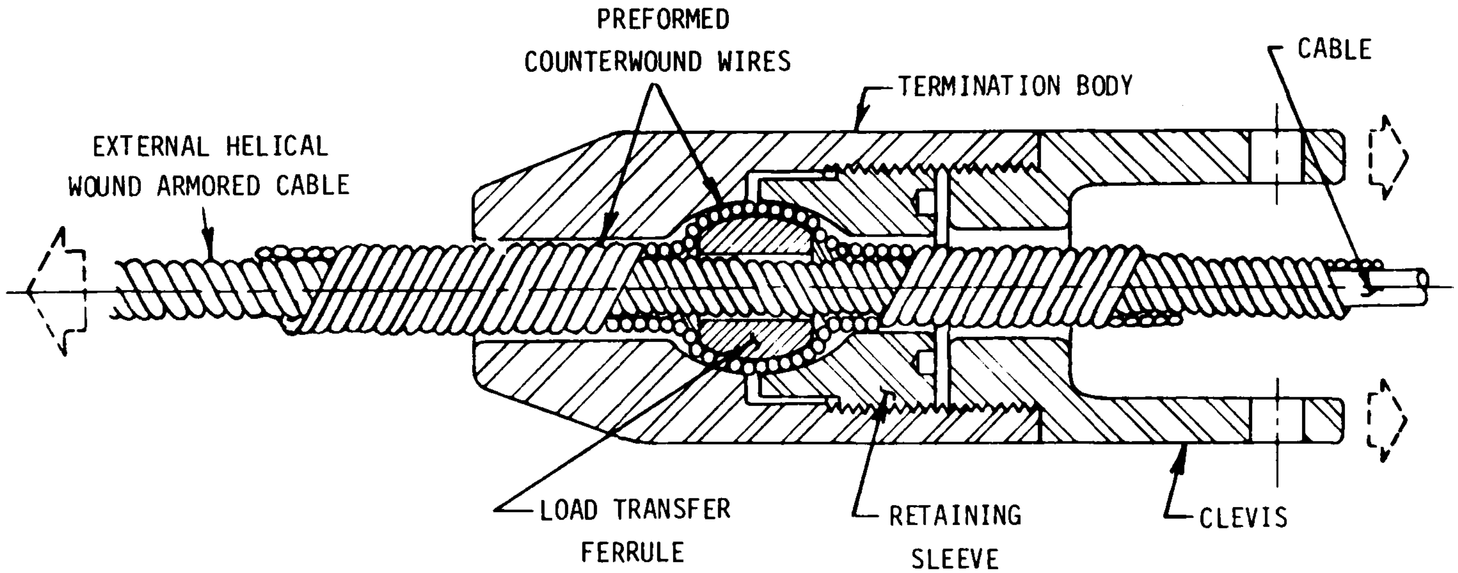


FIGURE 9-20 PREFORMED LINE PRODUCTS COMPANY TERMINATION METHOD FOR EXTERNAL COUNTERWOUND ARMOR

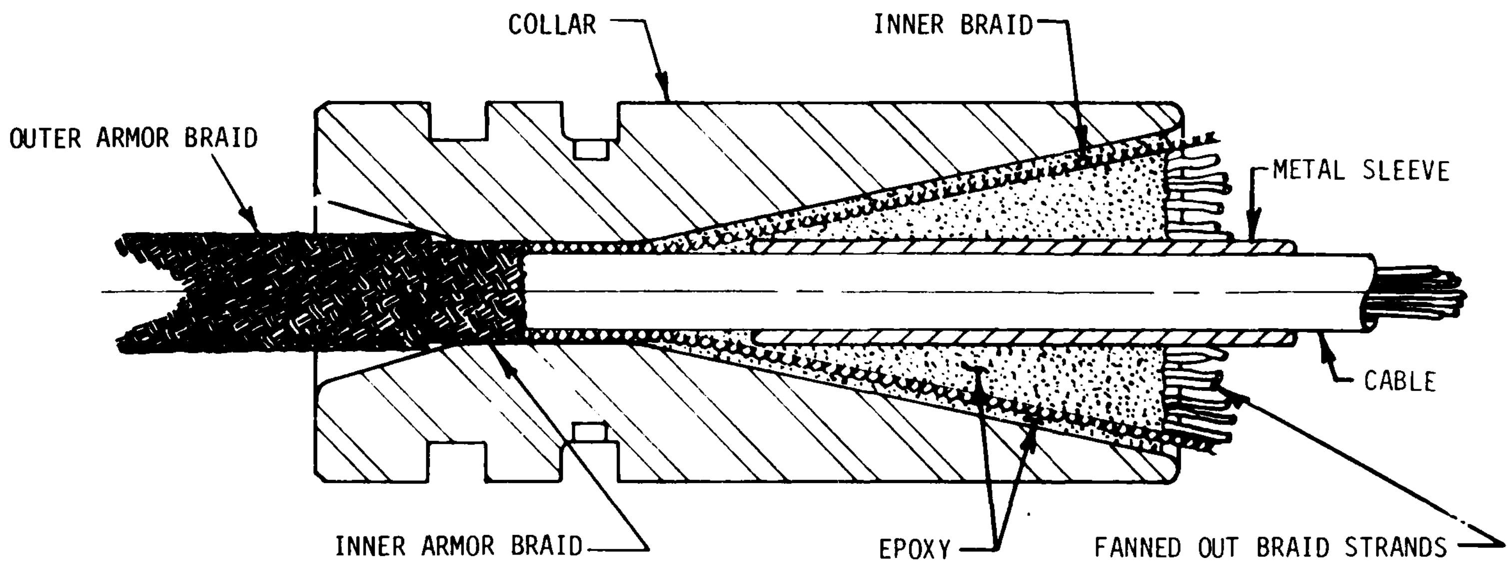


FIGURE 9-21 ĿPOXY POTTED TERMINATION METHOD FOR EXTERNAL BRAIDED ARMOR

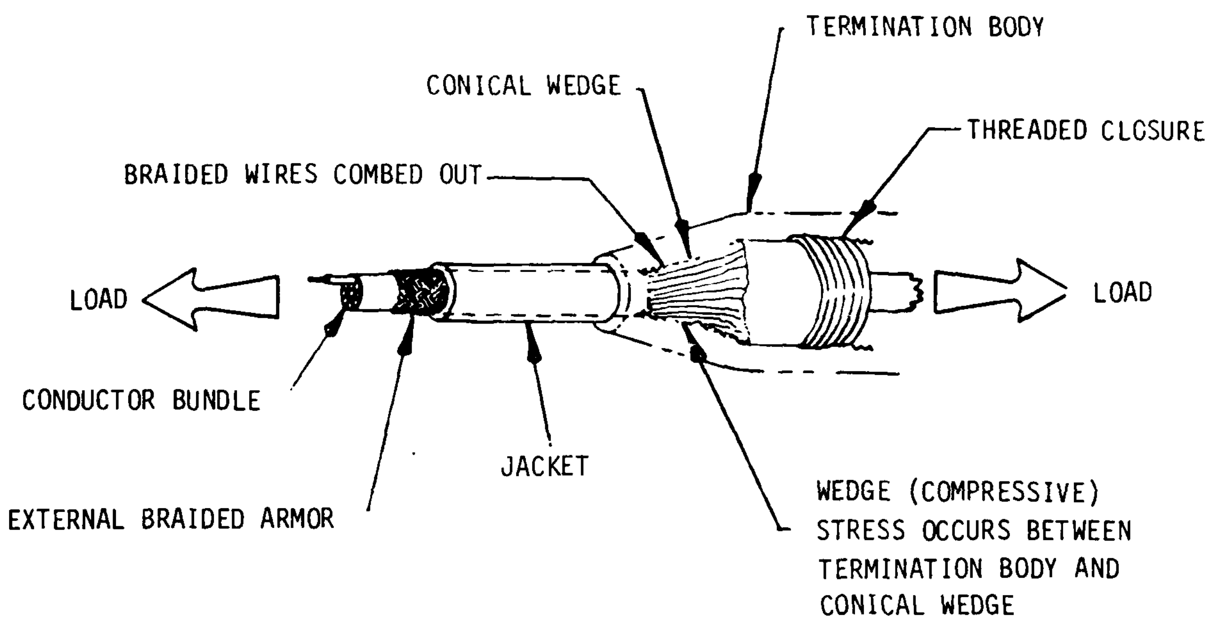


FIGURE 9-22 CONICAL WEDGE TERMINATION METHOD FOR EXTERNAL BRAIDED ARMOR

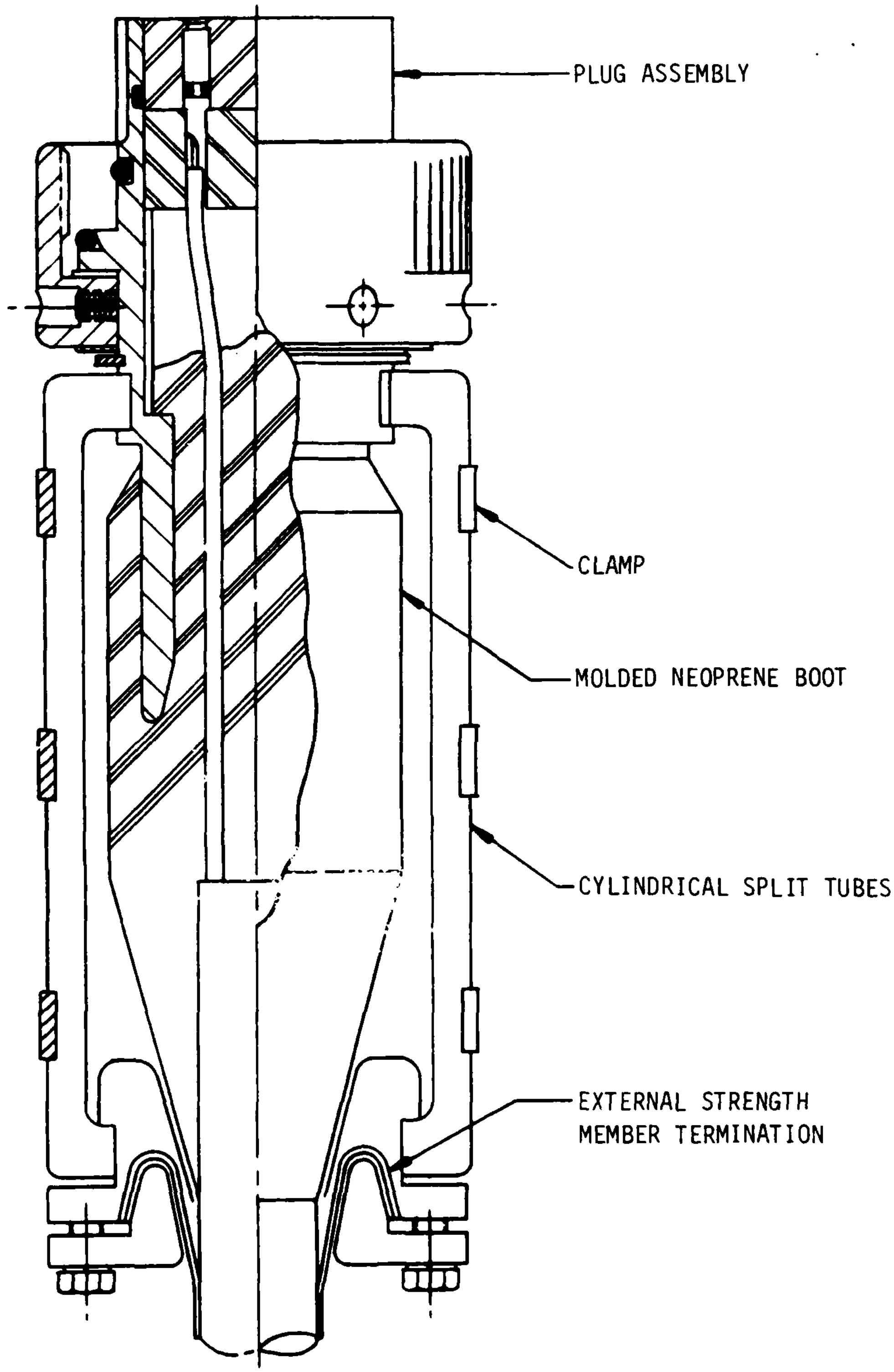


FIGURE 9-23 INTEGRAL STRENGTH MEMBER- CONNECTOR TERMINATION FOR EXTERNAL ARMOR

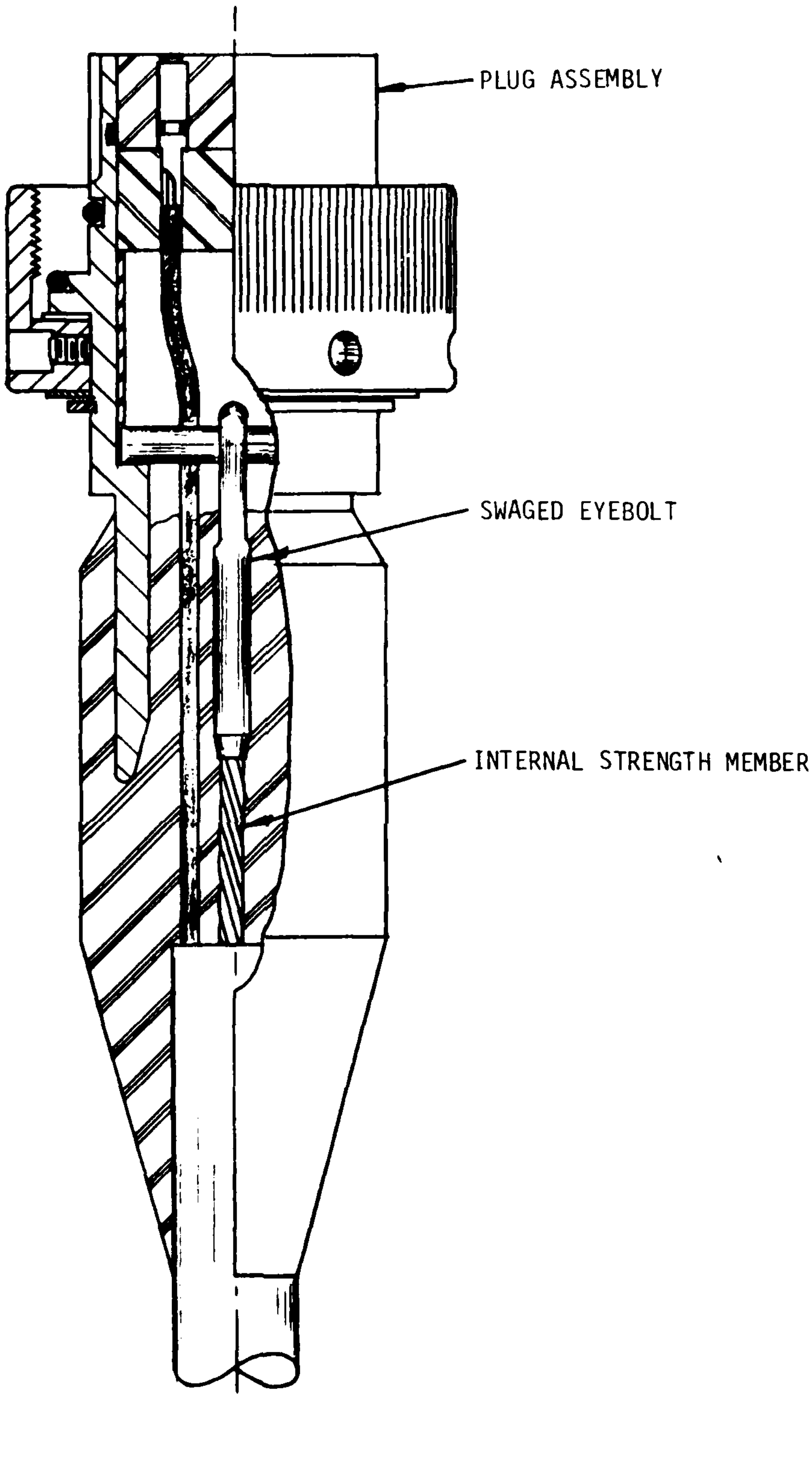


FIGURE 9-24 INTEGRAL STRENGTH MEMBER-CONNECTOR TERMINATION FOR INTERNAL STRENGTH MEMBER

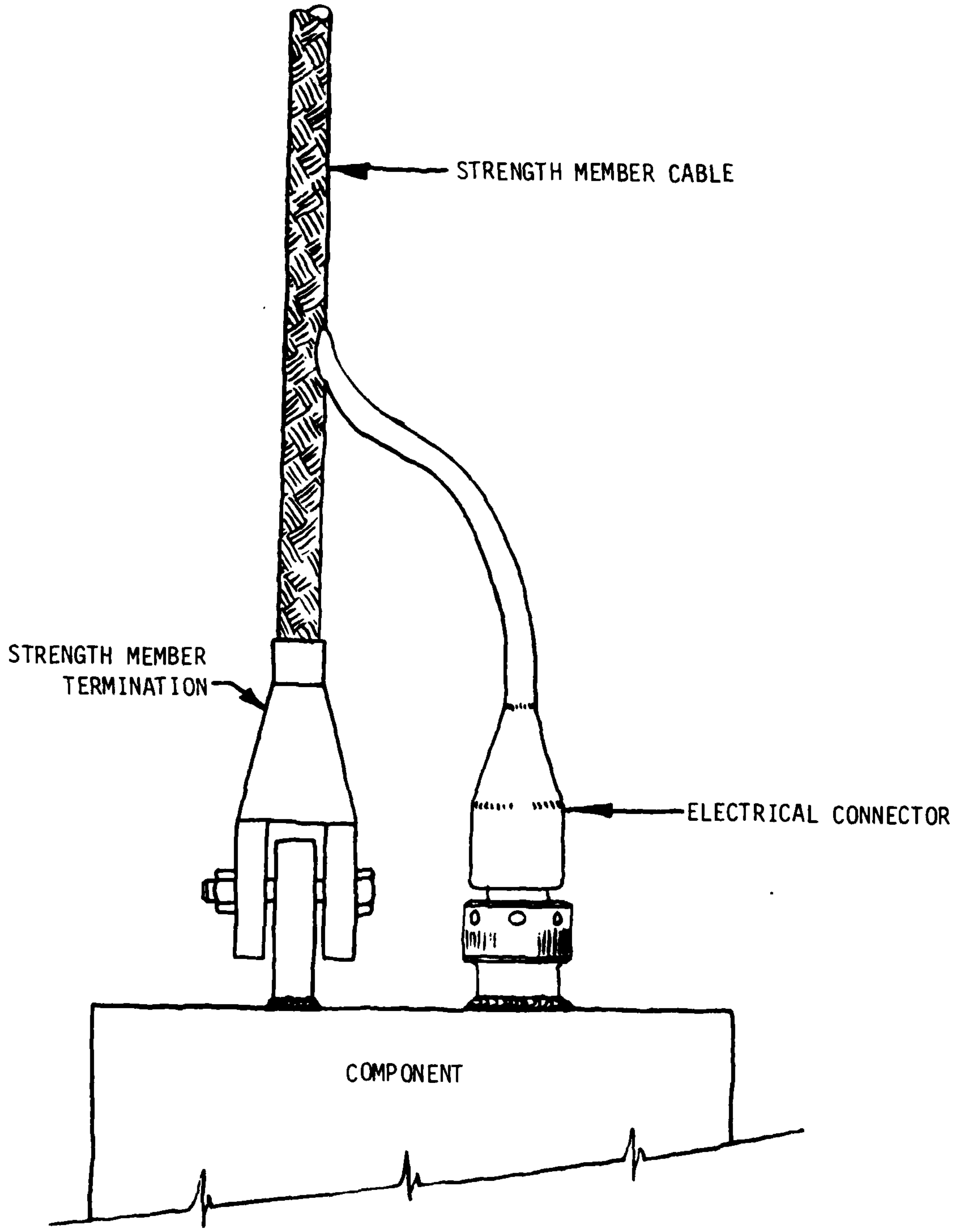


FIGURE 9-25 DISASSOCIATED STRENGTH MEMBER-CONNECTOR TERMINATION

REFERENCES

9-1 NAVSHIPS Drawing No. NR-1-302-2663185, "Wiring, Molding, Testing, Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators", Naval Ship Systems Command, Washington, D.C.

9-2 MIL-M-24041, "Molding and Potting Compo , Chemically Cured, Polyurethane (Polyether-Based)"

9-3 Lenkey, D. III, & Wyatt, W.W., "Polyethylene Bonding to Metal for Cable Penetration of Pressure Hulls and Communications Applications", 17th Annual Wire and Cable Symposium, Atlantic City, NJ, December 4-6, 1968.

9-4 Haigh, K.R., "Deep-Sea Gland System for Underwater Vehicles and Oceanographic Equipment", Proceedings, IEEE, Volume 115, January 1, 1968.

9-5 Hobaica, E.C., "Potting Compound Test Program", Memo of January 5, 1971 from EBDivision Non-Metallics Group to R. Haworth, File No.: P-734, DOT Contract No.: N00024-68-C-5434 (Included in Progress Report 23 of April, 1973.

9-6 Furane, Inc., "Safety Precautions to be Used in Handling Epoxy and Urethane Resins", Bulletin No. EP-54-8-D.

REFERENCES

(Cont'd)

9-7 Anderson, J.D., "Crimping Manual for the Electronic Industry", Burndy Corporation, Norwalk, CT, 1965,

9-8 NAVAIR 01-1A-505, "Technical Manual - Installation Practices for Aircraft Electric and Electronic Wiring", 1 July 1972.

9-9 Nowatzki, J.A., "Strength Member Design for Underwater Cables,", Electrodynamics Division Bendix Corporation, Sylmar, CA, 7th Annual Marine Technology Society Conference, Washington, D.C., August, 1971.

9-10 Bridges, R.M., "Structural Requirements of Undersea Electrical Cable Terminations," Electrodynamics Division, Bendix Corporation, Sylmar, CA, 7th Annual Marine Technology Society Conference, Washington, D.C., August,1971.

9-11 Hagmann, R., "Load Carrying Capabilities of Armor Electrical Cables", Viking Industries, Inc., Chatsworth, CA, May, 1965. Report No. VTR235.

9-12 Capadona, E.A., & et al., "Dynamic Testing of Cables", 2nd Annual Marine Technology Society Conference, June 26-29, 1966.

REFERENCES

(Cont'd)

9-13 Bridges, R.M., "Undersea Cable System Design for the Eniwetok BMILS Installation", 6th Annual Marine Technology Society Conference, June 29-July 1, 1970.

9-14 Czul, E.C., & Gennari, J.J., "Load-Carrying Terminals for Armored Electrical Cables", U.S. Naval Research Laboratory, Washington, D.C., Report 6261, August 31, 1965. AD621564.

SECTION 10

CONNECTOR MOLDING AND FABRICATION PROCEDURES

LIST OF FIGURES

LIST OF TABLES

10.1 General

This section describes methods of wiring and molding outboard electrical cables to pressure-proof connectors and cable glands. Cable/connector molding methods include polyurethane rubber to MIL-C-24231 connectors; neoprene rubber to MIL-C-24217 connectors; polyurethane rubber to MIL-C-24217 connectors; butyl rubber to MIL-C-24231 connectors; neoprene rubber to MIL-C-24231 connectors; ethylene propylene diene monomer to cable glands; and polyethylene to connectors and cable glands.

The methods described in this section have been taken from the Navy documents prepared by various agencies to meet the particular needs of a submarine or submarine sonar system.

Regardless of the wiring and molding method used, the procedures should address the following major areas of concern:

1. Safety precautions.
2. Harness wiring schematics.
3. Cable inspection.
4. Connector inspection.
5. Cable end preparation.
6. Connector cleaning.
7. Connector sandblasting.
8. Mixing primers.
9. Priming the connector.
10. Terminating the conductors to contacts
    - Soldering
    - Crimping.
11. Priming the cable,
12. Preparing the mold.

10.1 (Continued)

13. Assembling the cable/connector in the mold.
14. Preheating the mold.
15. Preparing the molding compound.
16. Molding the cable/connector.
17. Trimming the mold flashing.
18. Inspecting the molded harness.
19. Testing the harness.
20. Packaging the harness.
21. Wiring/molding personnel qualification.
22. Capital equipment list.
23. Tooling list.
24. Non-consumable material list.
25. Consumable material list.

The connectors and cable glands are wired and molded to the cables in accordance with the Navy approved procedures which follow:

NOTE

A NUMBER OF PROCEDURE FORMAT AND NOMENCLATURE CHANGES HAVE BEEN MADE FROM THE ORIGINAL PROCEDURE DOCUMENTS NOTED IN THIS SECTION FOR STANDARDIZATION PURPOSES.

10.2 Safety Precautions

1. Do not smoke or use an open flame in the working area. Methyl ethyl ketone (MEK) is highly flammable.

2. Be sure the working area is well ventilated to prevent excessive exposure to the toxic vapors.

3. Avoid excessive contact with solvents, primers, and compounds. Wear rubber, lightweight cotton, or plastic gloves. Splashes or spills should be washed from the skin immediately with soap and water.

4. Use safety cans for transferring and storing solvents. Solvents may be transferred to smaller safety cans or 1-pint polyethylene wash bottles for ease of handling. During use, however, do not pour solvents into open containers.

5. Do not leave solvent-saturated rags and paper wipes in the work area. Place them in safety waste cans immediately after use.

10.3 Cable Inspection and Handling Procedures

It is important that the cable used to fabricate harness assemblies is of the correct type, has been fabricated according to specifications, and has not been damaged during handling, shipping, or storage. Inspection of cable before fabrication will prevent assembly difficulties or early failure of completed harnesses.

Procedures for cable inspection are given in this section to permit positive identification of the cable.

The following procedure should be used to ensure a satisfactory molded cable harness assembly for outboard use on submarines:

1. Measure the exact length required for the outboard cable run.
2. Visually determine that the cable is the required type by comparing it to the applicable specifications.
3. Carefully remove the cable from the reel, visually inspecting the cable jacket throughout the cable length for nicks, cuts, abrasions, or scratches that might lead to a punctured jacket either at installation or in service.

   NOTE

   IMPERFECTIONS CAN BE NOTED BY COMPLETE VISUAL INSPECTION AND RUNNING A HAND OVER THE ENTIRE LENGTH TO FEEL NICKS, SCRATCHES, INDENTS AND BUBBLES.

   If a jacket is damaged, cut the cable at this point and remove the damaged section. Retain the undamaged portion of the cut cable for future use where a shorter length is required.

10.3 (Continued)

4. Cut a piece of cable of the required length from the cable reel.

5. Check the cable diameter at the ends of the cable with a micrometer to be sure that they conform to the specification. The diameter must be as specified to ensure proper wiring to the plug assembly and proper molding.

6. Check the cable for continuity and megger for low insulation resistance and shorts.

7. Place the cable in a plastic bag or other suitable container to prevent damage and to ensure proper storage and handling prior to wiring the plugs and subsequent molding operations.

10.4 Plug and Receptacle Inspection and Handling Procedures

Inspect all plugs and receptacle parts before assembling with cables to ensure that they are the correct type, have been manufactured correctly, are undamaged, are missing no parts, and are clean. Check each socket contact with a minimum and maximum diameter gage pin in accordance with Table 10-1.

10.4.1 Plug Inspection Procedures for MIL-C-24217 Plugs

Use the following plug inspection and handling procedures to ensure satisfactory molded cable harness assemblies.

NOTE

WORK IN A CLEAN BENCH AREA.

1. Remove the plug assembly from the storage bag.
2. Disassemble the plug assembly-plug shell, non-ferrous metal protective cap, coupling ring, socket contacts, front insulator, rear insulator, retaining rings, and thrust washer.
3. Visually inspect the coupling ring to see that the threads are fully deburred. Mate the ring with a thread gage or test receptacle to ensure proper threading at installation.
4. Visually check O-ring groove surfaces on the plug shell to ensure that they are free of nicks and scratches. The rear face of the plug shoulder should be smooth to prevent galling when mating with the coupling ring.

TABLE 10-1

Contact Gage* Dimensions

Contact Size	Minimum Pin Diameter (Inch) +.0002, -.0000	Maximum Pin Diameter (Inch) +.0002, -.0001	Socket Contact Bore Depth (Inch, Minimum)
No. 16	.0615	.0635	.245
No. 12	.093	.095	.625
No. 8	.141	.143	.625
No. 4	.224	.226	.625
No. 0	.356	.358	.625

* Contact gages available from:

Electronic Connectors, Inc.,
146-10 Jamaica Ave.
Jamaica, New York, 11435

10.4.1 (Continued)

5. Check the insulators with the appropriate NAVSHIPS drawing to ensure that the contact positions are properly marked on the front and rear faces of the insulator.

6. Check each socket contact with a minimum and maximum diameter gage pin in accordance with Table 10-1. Ensure that the spring in the socket contact is engaged when the test pins are inserted. Also check that the pins properly bottom in the cavity of the socket contact bore in accordance with Table 10-1. As a final check, mate plugs with a corresponding receptacle type gage to ensure mating ability onboard ship.

7. Check the plug for proper keyway location.

8. Check the critical plug sleeve dimensions (shown in Figure 10-1).

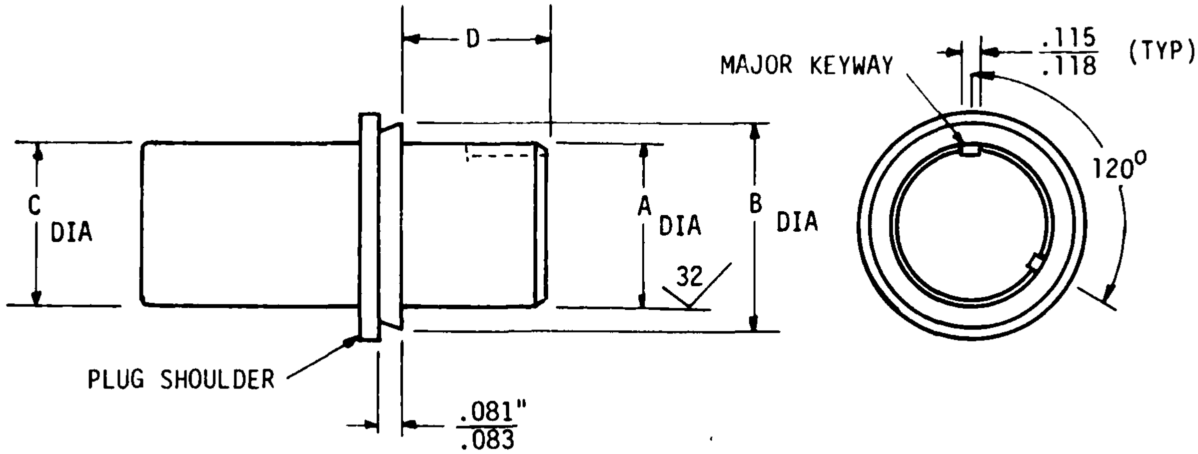
9. Place the individual plug parts in plastic bags and store them in a container while the plug shell is being prepared for wiring and molding.

10.4.2 Receptacle Inspection Procedures for MIL-C-24217 Receptacles

Use the following receptacle inspection and handling procedures to ensure satisfactory molded cable harness assemblies. See figure 2-4.

NOTE

WORK IN A CLEAN BENCH AREA.



PLUG TYPE	DIMENSIONS A	B	C	D
3 No. 16	.623 / .621	.850 / .840	.875 / .873	.720 / .730
5 No. 16	.812 / .810	1.163 / 1.153	1.062 / 1.060	.720 / .730
5 No. 16 (SPL)				
9 No. 16	1.058 / 1.056	1.413 / 1.403	1.187 / 1.185	.720 / .730
14 No. 16	1.308 / 1.306	1.792 / 1.782	1.502 / 1.500	.720 / .730
24 No. 16	1.690 / 1.688	2.167 / 2.157	1.875 / 1.873	.720 / .730
3 No. 12	1.058 / 1.056	1.413 / 1.403	1.187 / 1.185	1.183 / 1.188
3 No. 8	1.308 / 1.306	1.792 / 1.782	1.502 / 1.500	1.183 / 1.188
3 No. 4	1.690 / 1.688	2.167 / 2.157	1.875 / 1.873	1.183 / 1.188
3/8-3/12	1.690 / 1.688	2.167 / 2.157	1.875 / 1.873	1.183 / 1.188
3 No. 0	2.312 / 2.310	2.845 / 2.840	2.500 / 2.498	1.183 / 1.188
5 No. 16	.623 / .621	.850 / .840	.875 / .873	.720 / .730
5 No. 16 (SPL)	.812 / .810	1.163 / 1.153	1.062 / 1.060	.720 / .730
3 No. 12	1.056 / 1.058	-	1.187 / 1.185	1.183 / 1.188
14 No. 16	1.308 / 1.306	1.792 / 1.782	1.502 / 1.500	.720 / .730
RG-17A/U (MOD)	1.496 / 1.497	1.775 / 1.780	1.748 / 1.752	3.901 / 3.905

FIGURL 10-1 CRITICAL PLUG SLEEVE DIMENSIONS - MIL-C-24217 PLUGS

1. Remove the receptacle assembly from the storage bag.

2. Disassemble the receptacle - front protective cap, receptacle body, tailpiece, rear protective cap, and O-ring.

3. Visually inspect the receptacle threads to see that they are fully deburred. Mate the receptacle with a thread gage or test coupling ring to ensure proper threading at installation.

4. Visually inspect the O-ring groove surface on the face and the rear of the receptacle, and the O-ring groove in the receptacle bore and tailpiece to ensure that they are free of nicks and scratches. See figure 7-6 for location.

5. Check the threads on the rear of the receptacle and the tailpiece and ensure that they engage properly.

6. Check the location of the contacts and keys in the receptacle with the appropriate NAVSHIPS drawing to ensure that the contacts are properly marked on the front and rear faces of the receptacle header section.

7. Inspect the pin contacts for their ability to mate with their respective socket contacts.

8. Check (a) insulation resistance of contacts (contacts-to-shell) and (b) withstanding voltage of contacts (contacts-to-shell) for compliance with the applicable receptacle drawing.

9. Mate the receptacle with a test plug to ensure that the plug shoulder seats properly on the face of the receptacle.

10.4.2 (Continued)

10. Check the receptacle for proper key location.
11. Check receptacle critical demensions.
12. Check O-ring size and groove dimensions.
13. Reassemble the receptacle including protective cap and store it in a bag and container until needed for molding to the cable.

10.4.3 Plug Inspection Procedures for MIL-C-24231 Plugs

Use the following plug inspection and handling procedures to ensure satisfactory molded cable harness assemblies.

NOTE

WORK IN A CLEAN BENCH AREA.

1. Remove the plug assembly from the storage bag.
2. Disassemble the plug assembly - plug cap, coupling, plug shell and molded insert.
3. Visually inspect the coupling to see that the threads are fully deburred. Mate the coupling ring with a thread gage or test receptacle to ensure proper threading at installation.
4. Visually inspect the O-ring seal surfaces on the inside lip of the plug shell to ensure that they are free of nicks and scratches. The rear shoulder of the plug shell should be smooth to prevent galling when mating with the coupling.

10.4.3 (Continued)

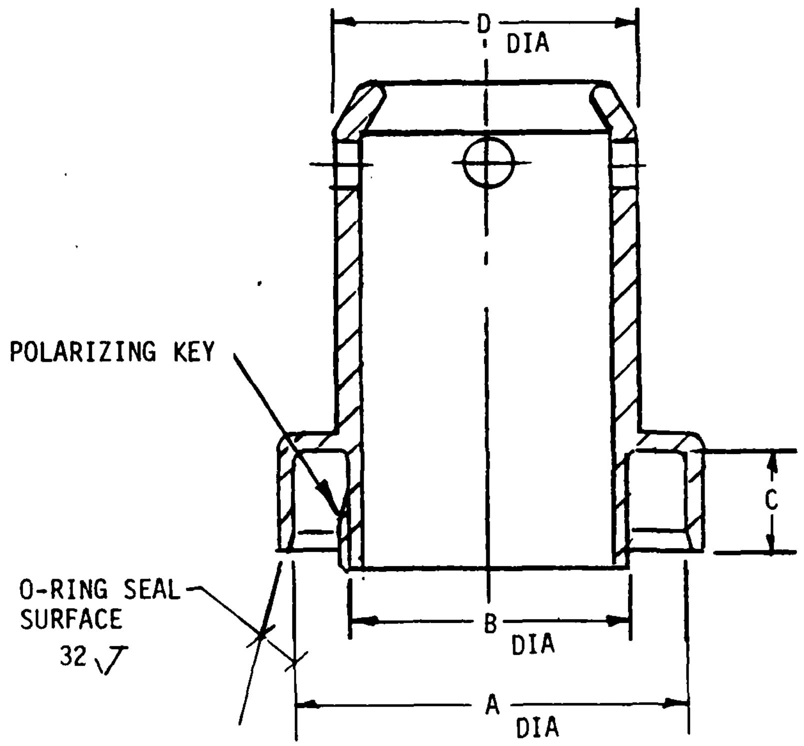
5. Inspect the socket contacts for their ability to mate with their respective test pins.

6. Check the molded insert with the appropriate NAVSHIPS specification sheet to ensure that the contact positions are properly marked on the front face of insert.

7. Check the critical plug sleeve dimensions (shown in Figure 10-2).

8. Store the individual plug parts in clean plastic bags and a container while the plug shell is being prepared for wiring and molding.

9. Check insulation resistance of socket contacts in molded plug insert.



PLUG SLEEVE PART NO.	PLUG TYPE	DIMENSIONS A	B	C	D
M24231/1-010	3 & 4 CONDUCTOR	1.313 / 1.309	.874 / .869	.505 / .495	1.036 / 1.026
M24231/3-010	7 & 9 CONDUCTOR	1.627 / 1.623	1.186 / 1.181	.505 / .495	1.346 / 1.338
M24231/4-010	14, 24, 30, 40	2.377 / 2.373	1.624 / 1.619	.599 / .589	1.816 / 1.806

FIGURE 10-2 CRITICAL PLUG SLEEVE DIMENSIONS - MIL-C-24231 PLUGS

10.5 Polyurethane Rubber Molding MIL-C-24231 Plugs

MIL-C-24231 pressure-proof connectors are wired and polyurethane molded in accordance with the Portsmouth Naval Shipyard developed procedures detailed in Reference 10-1. The Portsmouth Naval Shipyard Rubber and Plastics Laboratory, Kittery, ME, conducts a number of training courses each year for the Navy submarine tender shop and Naval Shipyard personnel in the area of wiring and molding pressure-proof cable harnesses. The following wiring and molding procedures are excerpted from the Reference 10-1 document.

10.5.1 Monel Plug Sleeve Preparation

1. First check and clean plug sleeve. Protect the unsandblasted portions of plug sleeve with masking tape or suitable masking jigs made fr[illegible] rubber, teflon, or similar material. (See Figure 10-3). Sandblast those portions which will be covered with the molding compound with #50 angular steel grit.
2. Thoroughly clean the plug sleeve with Acetone or Methyl Ethyl Ketone and allow to dry. Do not contaminate sandblasted surfaces with fingers or in any other way after cleaning. If surface becomes contaminated before primer is applied, reclean.
3. The plug sleeve should be primed just prior to the molding operation. The base component of the metal primer must be thoroughly stirred before using. Use steel or glass rods. Carefully measure or weigh out the two components of the primer in polyethylene or metal container and mix with a clean spatula.

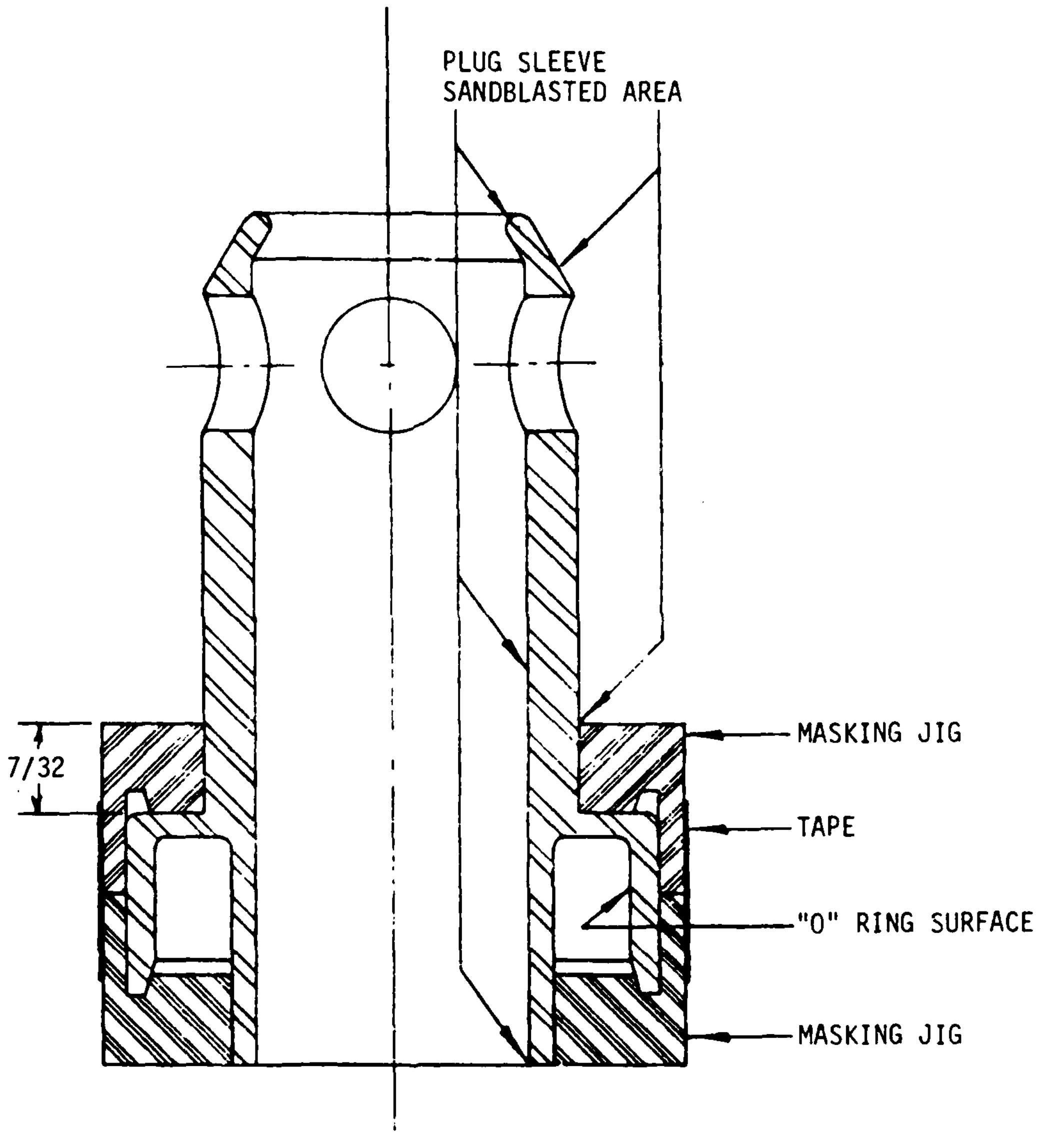


FIGURE 10-3 MIL-C-24231 PLUG SLEEVE SANDBLAST AREA

10.5.1 (Continued)

4. Using a brush apply a thin even film of metal primer, in accordance with the Compound Supplier's Technical Data Sheets, to the inside and outside sandblasted surfaces of the plug sleeve, using a brush. Extend the primed surface on the outside of the sleeve 1/16 inch beyond the surface to be covered with molding compound. Allow the primer to dry in accordance with Technical Data Sheet instructions. Do not force dry using an external heat source such as a hot air gun.
5. Primed surfaces should not be touched with fingers or contaminated in any other way.

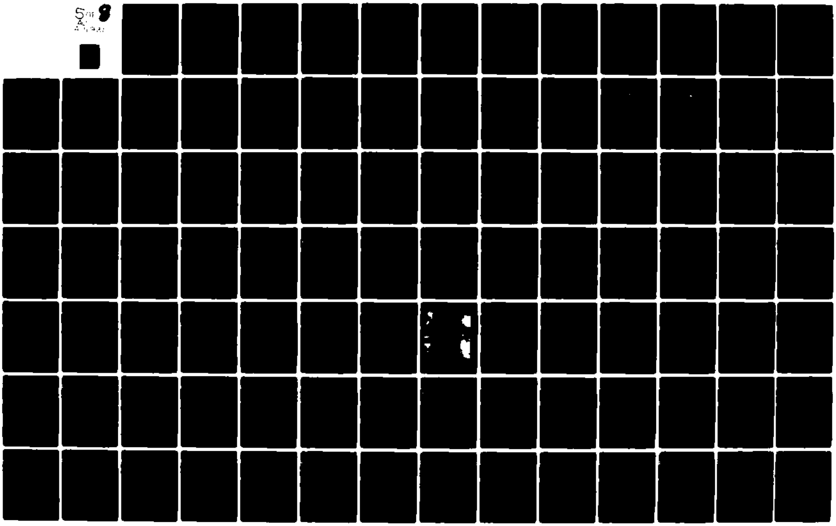
10.5.2 Preparation of Cable End

1. Remove 3/4 to one inch of the outer jacket from the cable end, being careful not to cut the braided shield (Figure 10-4).
2. If the braided shield is to be wired to a socket contact, comb out shield and gather and twist together enough strands to equal conductor size of the cable being wired. Position twisted shield strands to line up with its respective socket contacts. Some cable constructions have inner shields bonded to the outer jacket. In these cases, the shield may be pulled free with the piercing awl to allow for combing and cleaning of the individual strands with Acetone or Methyl Ethyl Ketone. If the braided shield is to be terminated at the plug, trim the shield at the outer jacket termination by beveling the outer jacket away from the braided shield (see Figure 10-4B). Some cables have a double

AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

UNCLASSIFIED NRL-MR-4601 NL

5 of 8



1193

1.0 2.5 2.8 3.2 3.6 4.0 4.5 5.0 5.6 2.2 2.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

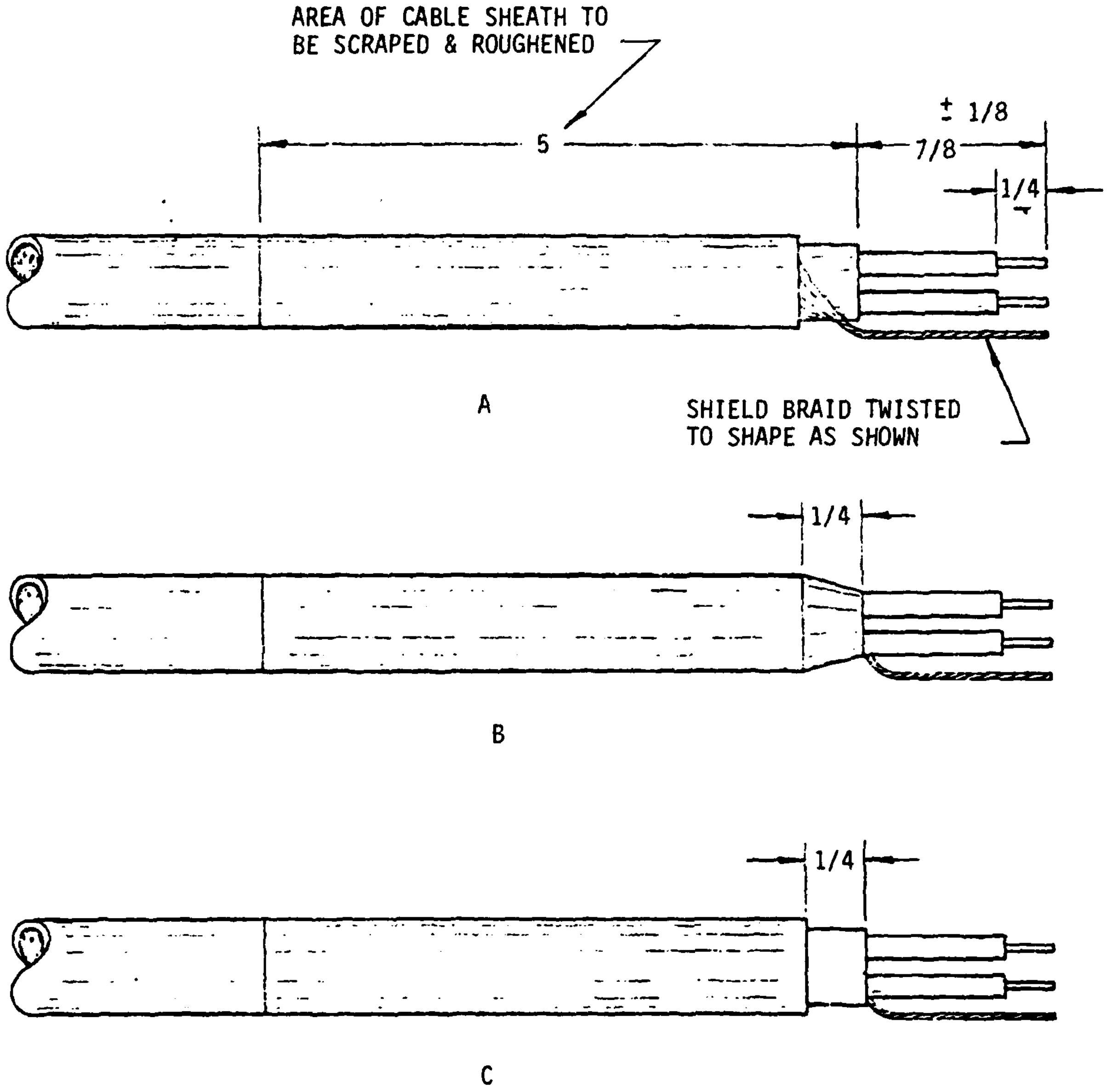


FIGURE 10-4 CABLE END PREPARATION

10.5.2 (Continued)

2. layer jacket over the shield with the outer jacket having rather low insulation resistance qualities. These cables shall have the outer jacket cut and removed 1/4 inch back of the inner jacket per Figure 10-4C, to prevent the braided shield from contacting any portion of the cable outer jacket.

3. Cut and remove cable fillers from between individual conductors.

4. Trim conductors and shield as shown in Figure 10-4A.

5. Untwist stranded wires of individual conductors and remove sealing compound from strands. Retwist conductor strands tight.

10.5.3 Prepotting the Plug Inserts

The prepotting of molded inserts using MIL-M-24041 polyurethane molding compound, before the socket contacts are soldered to the conductors, is required for all sizes of MIL-C-24231 connector plugs. Prepotting prevents socket contacts from pulling away from the loading pins of mold aligning head during the molding operation and prevents molding compound from flowing into the "O"-ring area of the plug sleeve.

Preformed molded inserts should be kept available for the sizes most often needed. The molding operation for preformed molded inserts is as follows:

10.5.3 (Continued)

1. Slip plastic sleeving over each socket contact.
2. Assembly socket contacts on the corresponding loading pins of mold aligning head pin bushing. Push plastic sleevings down so that they contact the shoulder on the loading pins. Socket contact solder cups should all face in the same direction.
3. Place the teflon coated preformed ring in place on the pin bushing as shown in Figure 10-5.
4. Fill areas around the socket contacts with polyurethane molding compound to the top of the preformed ring. Allow mold to stand until all entrapped air bubbles rise to the surface, approximately 15 minutes. Add more compound even with the top of preformed ring, if necessary. Take care to avoid getting any compound on the solder cup portion of the socket contacts.
5. Place the filled preformed mold into 180°F oven for 7 hours.
6. Remove the unit from the oven and allow to cool. Remove preformed ring and the cured molded insert from the pin bushing and visually inspect for defects.

10.5.4 <u>Soldering Socket Contacts to Conductors</u>

1. Assemble the previously primed plug sleeve with its corresponding metal coupling ring and slide them over the end of the prepared cable. Allow sufficient room away from cable end to work confortably with the soldering operation.

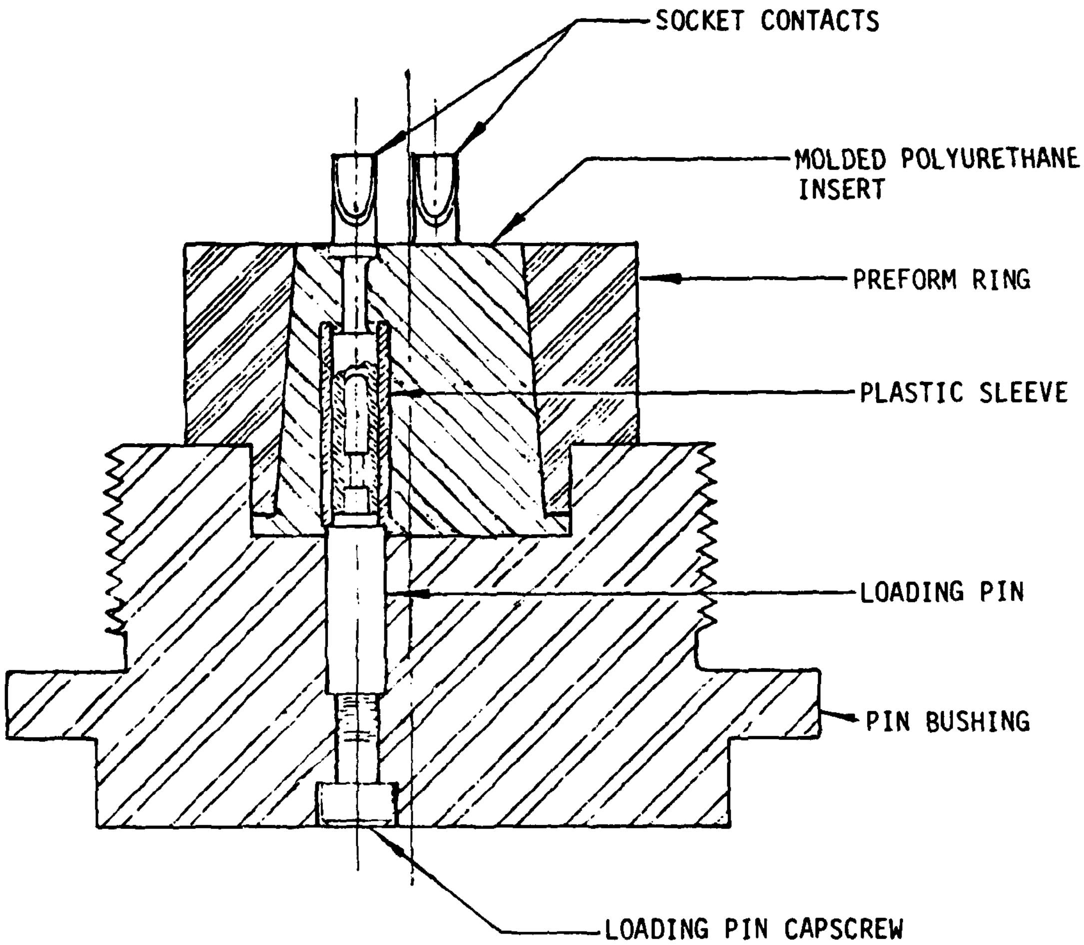


FIGURE 10-5 MIL-C-24231 PLUG INSERT MOLD

10.5.4 (Continued)

2. Unless otherwise specified by a special requirement, the individual conductors shall be soldered to the corresponding socket contacts of the preformed molded insert in accordance with the Tables of connections and slant sheets, /1, /2, /3, /4, and /23 of MIL-C-24231. The soldering is accomplished using the following techniques:

3. Tin the conductors and ends of the shields by placing them on a clean pre-tinned soldering iron and allowing the applied solder to flow through to the soldering iron.

4. Tin the solder cups of the socket contacts by loading each cup with solder. Then flush out the excess solder while it is still molten. Take CARE to prevent ANY solder FROM remaining on the polyurethane compound between ADJACENT sockets.

5. Hang the cable vertically so that the conductors are in a downward position and fit each individual conductor into the solder cup of the solder contact. Keep the primed plug sleeve far enough above cable end so that it does not interfere with soldering.

6. Place hot soldering iron across back of solder cup and apply solder to the cut away portion of solder cup and exposed wire. Immediately remove soldering iron without moving the wire. If the wire is removed at this stage, a cold soldered joint (frosted appearance) could result. Reheat the soldered joint if this happens. Solder should cover the wire, with the wire contour still visible.

10.5.4 (Continued)

Excess solder should be carefully removed from the outside of each contact and from surfaces of molded insert with a knife.

10.5.5 Cable Jacket Identification

1. Because of the many types and formulations of materials used for cable sheathing, it is very important that cable jacket material is properly identified so that correct surface preparation can be applied.

2. Neoprene, Hypalon, and thermosetting cable sheath identification: The DSS, FSS, TSS, MSS, 2SW, and MWF cables* are generally sheathed with Neoprene or possibly Hypalon. Neoprene and Hypalon are thermosetting compounds and can be identified by touching a hot soldering iron to a piece of removed part of the jacket. If jacket is either Neoprene or Hypalon, it will become hard, charred, and cracked. Hypalon can be distinguished from Neoprene by the paraffin type odor it gives off when the hot iron is being applied.

3. Polyvinyl chloride, polyurethane, polyethylene, and thermoplastic cable sheath identification. The THOF, MHFF, and TSP cables* are generally sheathed with polyvinyl chloride and the RG series cables with polyurethane or polyethylene. These polyvinyl chlorides, polyurethanes or polyethylenes are thermoplastic compounds and can be identified by touching a hot soldering

* MIL-C-915 cables

10.5.5 (Continued)

iron to a piece of removed part of the jacket. These materials will melt and string out when the sample is removed from the hot iron. Polyethylene can be distinguished from polyurethane by the paraffin type odor it gives off when the hot iron is being applied.

4. Cables shall be checked for continuity, insulation resistance, and visually for damage and compliance with dimensions. All cables shall comply with their respective specifications and rejected if they do not comply.

10.5.6 Cable Jacket Preparation

10.5.6.1 *Neoprene and Hypalon Cable Jacket Preparation*

1. Scrape area of cable jacket that is to be bonded with a knife to remove any waxes or excessive plasticizers. Then roughen cable sheath with the edge of a flat file or coarse sandpaper. (See Figure 10-4). Remove any loose particles of cable with a clean brush and clean roughened surface of cable jacket with Methyl Ethyl Ketone (MEK). Apply neoprene primer with a brush to the roughened sheath area. Allow primer to dry in accordance with manufacturer's instructions (see data sheets) before assembling into the mold for molding the connector.

10.5.6.2 *Polyvinyl Chloride and Polyurethane Cable Sheath Preparation*

1. Scrape area of cable sheath that is to be bonded with a knife to remove any waxes or excessive plasticizers and roughen cable sheath with the edge of a flat file or coarse sandpaper. (See Figure 10-4). Remove any loose particles of cable sheath with a clean brush and tackify roughened area of cable sheath with MEK. Apply a coat of polyvinyl chloride primer with a brush and allow primer to dry in accordance with manufacturer's instructions before assembling into the mold for molding the connector.

2. Some formulations of polyvinyl chloride and polyurethane sheath material may not require the use of a primer to obtain a good bond to the polyurethane molding compound. If the bond of the molding compound to the cable is inadequate, repeat molding procedure without using a primer on the cable.

10.5.6.3 *Precautions for Difficult to Bond Cable Sheaths*

1. Some cables which are sheathed with polyethylene or formulations which contain excessive plasticizers are very difficult to bond to. Whenever possible, these cables should be substituted with cables which will bond readily to the polyurethane molding compound. Many RG cables, formerly sheathed with polyethylene, are available with polyurethane sheaths. These cables will readily bond to polyurethane molding compound, MIL-M-24041. Bonding problems in the field should be referred to NAVSEA, Code 5433, or Portsmouth Naval Shipyard Rubber and Plastics Laboratory, for special bonding techniques.

10.5.7 Preparation of Polyurethane Molding Compound (MIL-M-24041)

Polyurethane molding compounds, specification MIL-M-24041, are available as a two component kit, Type I and in frozen premixed cartridges, Type II. The Category A materials are recommended for use over the Category B materials because they are less moisture sensitive.

Shelf life of the two component polyurethane is usually recommended by the manufacturer to be six months. However, experience has shown that, when stored at room temperature in the original tightly sealed containers, the qualified polyurethane molding compounds may be used up to one year from date of manufacture.

Storage life of the one component premixed frozen cartridge is seven (7) days at -20^{o}F, fourteen (14) days at -50^{o}F and 60 days at -120^{o}F.

Submarine tenders should have freezer storage facilities capable of maintaining temperatures of -120^{o}F. The advantage of using premixed frozen cartridges is that they can be thawed out, ready to use in 30 to 45 minutes, while the two component material requires three to five hours for heating, mixing, and degassing. Also, any mixed two component compound that is surplus may be frozen in polyethylene cartridges and stored for future use. It is recommended that a supply of mixed, degassed, and frozen cartridges be made up from the two component compound and kept available.

Frozen cartridges may be thawed out by placing upright in an oven, heating block, or in a water bath at a temperature of 130^{o} for twenty minutes. Remove from heat and work the pliable cartridge case with hands to distribute temperature evenly. Replace cartridge at 130^{o}F for five more minutes. Remove cartridge from heat, bleed any entrapped air from under the plunger.

10.5.7 (Continued)

CAUTION

THAWING TIME AND TEMPERATURE MUST BE CONTROLLED CLOSELY TO OBTAIN MAXIMUM APPLICATION LIFE IN THE SHORTEST THAWING PERIOD. WORKING LIFE WILL BE REDUCED BY AN INCREASE IN EITHER THE THAWING TIME OR TEMPERATURE. AN INCOMPLETE THAW WILL RESULT IF THAWING TIME OR TEMPERATURE IS REDUCED. IF A HOT WATER BATH IS USED, BE SURE WATER DOES NOT ENTER CARTRIDGE.

The following batch mixing instructions for two part units should be closely adhered to for preparing the polyurethane molding compound.

1. Loosen lid of the polyurethane prepolymer container (larger container of the two components) and insert a clean dial thermometer to indicate actual material temperature while heating. Heat the component in an oven to 180°F $\pm$ 5°F. The material may be stirred with the metal thermometer occasionally to hasten melting and to assure uniformity. The prepolymer base compound, ready to use, should be clear with no sign of haziness.
2. Concurrent with Step 1 above, loosen lid of curing agent (smaller container) and insert a second metal thermometer to indicate material temperature and to aid in stirring. The curing agent should be heated to 225 $\pm$ 5°F and occasionally stirred until the material becomes smooth in appearance with no sign of grittiness.

10.5.7 (Continued)

3. While the prepolymer and the curing agent are being heated, the preceding priming and preparation steps should have been performed on the cable and plug sleeve.

4. Remove the prepolymer and curing agent from the oven at approximately the same time. Thermometers should be carefully withdrawn from the containers and, with the aid of a small metal spatula, any material clinging to the thermometers shall be returned to the containers. Wipe spatula with a disposable paper tissue wetted with MEK before handling second component.

5. While the prepolymer material is still hot, transfer the entire contents to a metal or polyethylene container approximately twice the volume of the total material to be mixed. Utilize the small spatula to scrape the sides, top, and bottom of the prepolymer container.

6. Place the container with the prepolymer in a vacuum chamber and degas at a pressure of less than 5 millimeters of mercury. The material will foam and expand to a maximum, then the foam mass will collapse. Degas for at least 10 minutes after collapse of foam.

7. After degassing, allow the prepolymer to cool to room temperature (90^{o}F) before adding the curing agent. The curing agent should be allowed to cool prior to mixing with the prepolymer.

8. Transfer the curing agent with the aid of a small metal spatula to the container containing the prepolymer. Utilizing a larger metal spatula, mix the two components thoroughly. Slow mixing by hand is recommended to reduce whipping air into the mixture. The sides and bottom should be scraped to assure complete mixing.

10.5.7 (Continued)

CAUTION

UNDER NO CIRCUMSTANCES SHOULD THE POLYURETHANE BE MIXED WITH A WOODEN STIRRER. ALWAYS USE STIRRERS MADE OF METAL OR GLASS OR OTHER SUITABLE MATERIAL CONTAINING NO MOISTURE.

9. Degas the mixture at 5 millimeters of mercury or less, until foaming subsides. This takes approximately 5 minutes after collapse of foam.

10. Transfer the material to 6 fluid ounce size polyethylene sealant gun cartridges, plugged with polyethylene thread protectors.

11. Position plunger in the cartridge immediately after and insert a clean metal thermometer along the side of the cartridge to form a vent and push in plunger until all air is displaced between it and the compound.

12. The mixed two part polyurethane molding compound should be used within two hours after preparation.

13. Qualified polyurethane molding compounds are available in various size kits, consisting of prepolymer base compound and the companion activating curing agent. Mix whole kits only.

10.5.8 Preparation of the Mold

1. Check the identification plate installed in the mold to assure that the cable designation, part number, etc., agree with cable and connector plug to be molded. If the correct identification plate is not available, aluminum embossing tape may be used in its place to provide proper marking. CAUTION: Embossing tape must be installed in reverse to provide correct reading on molded plug. Use double coated pressure sensitive adhesive tape to hold embossing in mold cavity.

10.5.8 (Continued)

2. The clean teflon coated molds provide for adequate release of molded polyurethane plugs. Do not use any auxiliary silicone release agents as they might contaminate the bonding areas of the metal sleeve and cable.

10.5.9 Assembly Instructions for Molding Connectors

1. Clean the sides and top of the molded insert assembly with MEK or Acetone to remove any oil or contamination.
2. Slide the plug sleeve and coupling down over the molded insert and screw the coupling on the aligning head hand tight. Unscrew coupling and make sure plug sleeve is all the way down into the aligning head. Rescrew coupling in place.
3. Assemble the mold being careful not to contaminate the primed surfaces.
4. Place the mold assembly in the upright position ready for molding.

10.5.10 Molding Procedure for Connectors

1. Take a 6 ounce cartridge of polyurethane molding compound as prepared, and attach a 1/8 inch nozzle and place it in a pressure sealant gun.
2. Place nozzle of cartridge in the bottom fill hole, as shown in Figure 10-6. If plastic injection valve is used, screw valve into bottom fill hole of mold and insert cartridge nozzle into valve and proceed with filling mold cavity as described below. Slowly force molding compound into the mold using 20 pounds of air

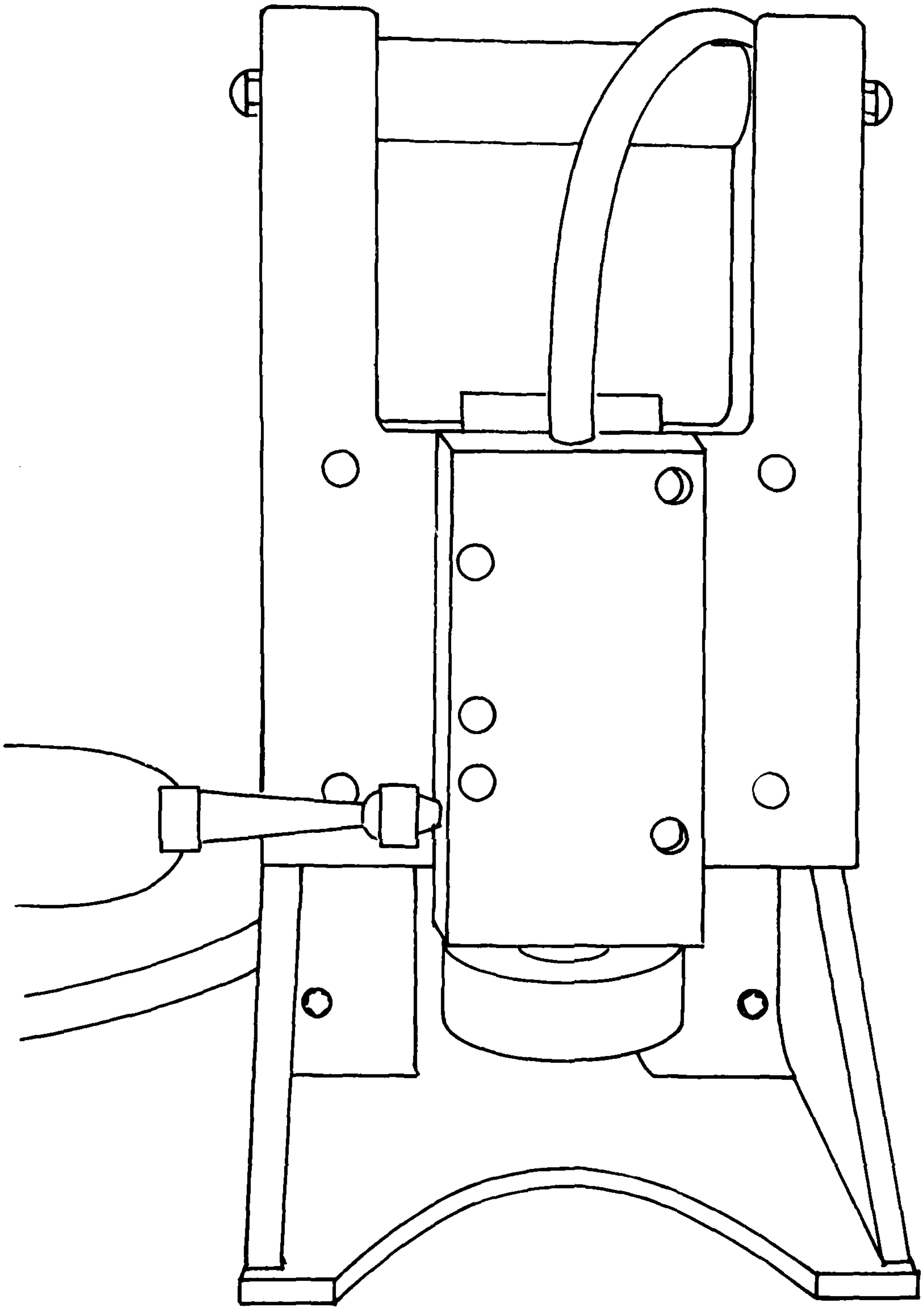


FIGURE 10-6 INJECTION OF POLYURETHANE INTO MOLD

10.5.10 (Continued)

pressure. Fill the mold with molding compound until level reaches vent hole located in the middle of the mold. Insert a plug into the middle vent hole and allow approximately 5 minutes for the molding compound to flow into the inside cavity of the plug sleeve. Continue to force molding compound into mold until it comes out the vent holes located in the top of the mold. When the 6-oz. cartridge is empty, replace with a full one and continue with the operation. Stop filling to allow trapped air in molding compound to rise to top of mold cavity, approximately 4-5 minutes, then continue with the filling operation allowing sufficient compound to bleed from top vent holes until all air is displaced from the mold. Keep wiping away excess compound so that air bubbles will be visible as they rise to the top. Withdraw nozzle slowly from fill hole, keeping pressure on gun to assure that fill hole will be filled with compound. Plug fill hole with provided mold screw. If the plastic injection valve is used, simply withdraw sealant gun nozzle from injection valve, keeping pressure on gun to insure that valve will be filled with compound.

3. Adjust the mold heating platen temperature to 180°F and cure for 7 hours. Check the temperature of the mold periodically with a metal dial thermometer to assure accuracy of the curing temperature. If older type molds without self-contained heating platens are being used, place the mold in an 180°F oven for 7 hours to cure the plug.

10.5.10 (Continued)

4. After curing the plug, allow the mold assembly to cool. Remove the four securing socket head cap screws and screw two of them into the jacking holes. Disassemble mold, using the cap screws to jack the mold apart. Do not use screw drivers to force the mold apart as this will cause damage. Trim flashing from molded plug with a razor blade. Be careful not to cut into the cable sheath. Close trimming is not required.

5. Screw protective cap in place. Figure 10-7 shows a polyurethane molded MIL-C-24231 plug assembly.

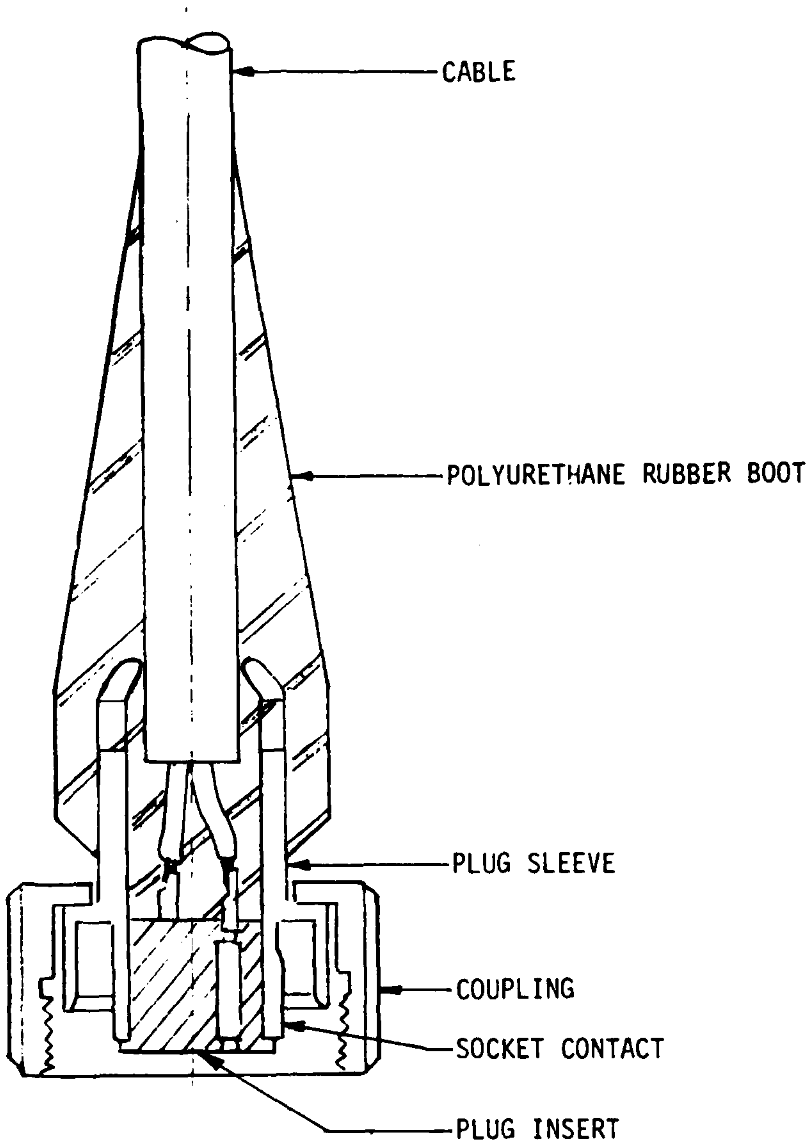


FIGURE 10-7 POLYURETHANE MOLDED MIL-C-24231 PLUG ASSEMBLY

10.6 Neoprene Rubber Molding MIL-C-24217 Plugs

MIL-C-24217 pressure-proof connectors are wired and molded in accordance with the Electric Boat Division developed procedures detailed in References 10-2 through 10-5. The most detailed Navy approved connector wiring and molding procedures have been prepared for the NR-1 deep submergence vehicle and are provided in Reference 10-2. These procedures provide for prepotting the connector plugs with polyurethane followed by molding a neoprene rubber cable boot.

The following wiring and molding procedures are taken from the Reference 10-2 document.

10.6.1 Preparation of Molding Compounds, Primers, and Adhesives

Polyurethane and neoprene molding compounds are used in the following fabrication procedures.

NOTE

THE USE OF THESE MATERIALS FOR PLUG MOLDING IS MANDATORY. THE LATEST QPL OR SPECIFICATION SHOULD BE CHECKED FOR THE LATEST ISSUE.

CAUTION

POLYURETHANE MATERIALS USED IN MOLDING PLUGS MUST BE PRODUCTS OF THE SAME MANUFACTURER. PRIMERS FROM ONE SOURCE MUST NOT BE USED WITH COMPONENTS FROM ANOTHER SOURCE.

MOLDING COMPOUNDS, ADHESIVES, PRIMERS, ETC., SHOWN IN TABLE 10-2 SHALL NOT BE USED AFTER EXPIRATION OF THEIR SHELF LIFE.

TABLE 10-2

Recommended Shelf Life for Perishable Materials

Material	Manufacturer's Shelf Life Unopened	Opened
Neoprene Molding Compound EBDiv. Spec. 2580	1 Yr, +40°F or Below	
Primer, Thixon P-4	6 Mos, at RT	See notes 1, 2, 3
Adhesive, Thixon NM-2	6 Mos, at RT	See notes 1, 2, 3
Polyurethane, Black PR-1547 Cat. A, Ty-2, Frozen Cartridge	7 Days, -20°F 28 Days, -90°F	Remainder discarded after use
Polyurethane, PR-1547, Amber Cat, A, Ty-2, Frozen Cartridge	7 Days, -20°F 28 Days, -90°F	Remainder discarded after use
Primer, PR-420	1 Yr, +80°F or Below	See notes 1, 2, 3
Primer, PR-1523M	3 Mos, +80°F or Below	See notes 1, 2, 3
Primer, PR-1543	3 Mos, +80°F or Below	See notes 1, 2, 3
Adhesive, PAC-136	6 Mos, at RT	See notes 1, 2, 3
Chemlok 205	1 Yr, at RT	See notes 1, 2, 3
Chemlok 220	1 Yr, at RT	See notes 1, 2, 3
Chemlok 304	1 Yr, at RT	See notes 1, 2, 3
Sealant, RTV-112	12 Mos, at RT	Discard surface cured material. Use remaining. See notes 1, 2, 3
Potting Compound, RTV-630	6 Mos, at RT	Discard surface cured material. Use remaining. See notes 1, 2, 3
Primer, SS-4120	6 Mos, at 50°F (See note 4)	See notes 1, 2, 3
Epoxy Resin-EPON 826	12 Mos, at RT	See note 1
Hardener-Sonite-41	Indefinite	See notes 1, 2, 3
Hardener-H-55	Indefinite	See notes 1, 2, 3

NOTES:

(1) Same shelf life if closed immediately after use.
(2) Contains volatile solvents and/or will readily absorb moisture. Leaving the cover off will cause degradation of material.
(3) Material should be discarded if both the following conditions occur: (a) container is opened more than 3 times, (b) less than 25% of the material is left in the container.
(4) Harmless precipitate may form. Do not shake. Pour off primers and use.

10.6.1.1 *Polyurethane* - Polyurethane molding compounds are available in frozen premixed cartridges. The compound is fabricated in accordance with MIL-M-0024041 (SHIPS). Only Category "A", Type II, material will be used. Check the latest issue of the Specification and Qualified Products List (QPL) before using material.

10.6.1.2 *Neoprene* - The neoprene molding compound for long-term salt water service is described in EB Specification 2580 (Reference 10-6). It should be freshened in a rubber mill before using. See Table 10-3 for the neoprene compound formulation.

Formulation of neoprene molding compound, and acceptance tests thereof, are described in Specification 2580. This specification also states minimum requirements for material stored up to one year. Molding with this type rubber will be done only with material from a certified batch. Certification dates and test information will be affixed to each bundle at the time of the test as well as the due date for the next certification.

10.6.1.3 *Primers and Adhesives* - When preparing primers and adhesives, stir them thoroughly to uniform consistency before use or mixing with other primers in two-part mixes. Two-part mixes should then be thoroughly stirred before applying. A mechanical shaker is recommended to guarantee complete, repeatable mixing.

When large cans of primers or adhesives are opened, it is recommended that the contents be thoroughly mixed and transferred to several two-ounce sealed jars, each jar containing a one-day supply. This is to prevent contamination of the adhesive supply. At the end of each work day, the workman will properly dispose of the unused compound in his container. Tightly seal primer and adhesive cans following use.

TABLE 10-3

NEOPRENE COMPOUND FORMULATION

	Components	Parts by Weight
1.	Neoprene WRT	80.0
2.	Neoprene KNR	20.0
3.	Neozone D	2.0
4.	Stearic Acid	0.5
5.	FEF Black	15.0
6.	MT Black	30.0
7.	Light Process Oil	4.0
8.	Red Lead	20.0
9.	Thionex	2.0
10.	Sulfur	1.0

NOTE:

(1) The compound is sufficiently safe to allow incorporation of all ingredients and still provide good storage life and handling characteristics. For maximum storage life, the material should be kept in a cold room at 40°F or below.

(2) From Reference 10-2.

(3) Molding temperature 305°F - 310°F.

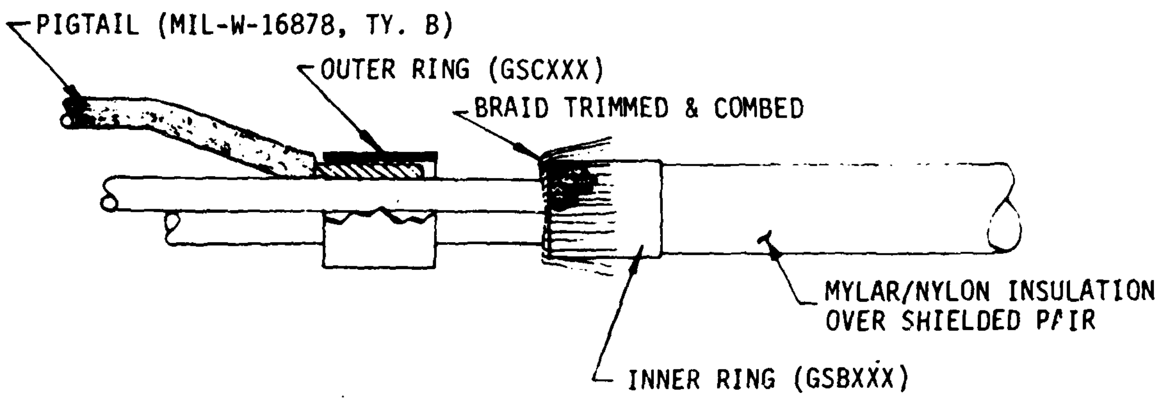
10.6.1.3 (Continued)

The perishable materials used in the molding operations described in this section are listed in Table 10-2. These materials will be dated on receipt by receiving inspection. Further, each individual unit shall be clearly identified with the appropriate expiration date in accordance with Table 10-2.

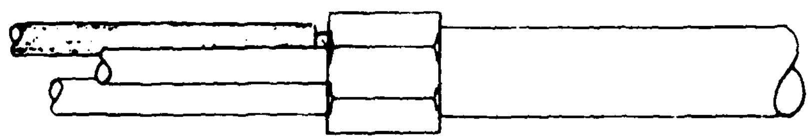
10.6.2 Cable Preparation

1. Carefully remove the neoprene outer jacket from the cable end with a knife. Do not cut the outer shield or conductor insulation. Check the inner insulation for nicks and cuts.
2. Remove any cable fillers to the termination of the outer jacket. Do not damage the outer shield or conductor insulation.
3. The general procedure for installing the shield terminal is shown in Figures 10-8 and 10-9.
4. Using a hot wire stripping tool, carefully remove the nylon jacket and conductor insulation from the conductor ends. Check conductors for freedom from cuts and nicked strands. Cut and/or nicked strands are cause for rejection.
5. Where required, cover bared conductors and shield connections with Kynar heat shrink tubings. Shrink the tubing using a hot air gun. Use the thermal stripping tool to trim the shrink tubing.

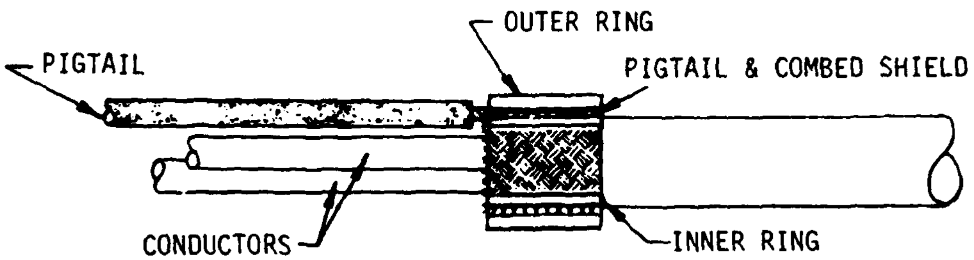
NOTE: IF SHIELD IS NOT CARRIED THROUGH THE CONNECTOR PREPARE IN SAME MANNER EXCEPT DO NOT INCLUDE THE PIGTAIL



(A) EXPLODED VIEW

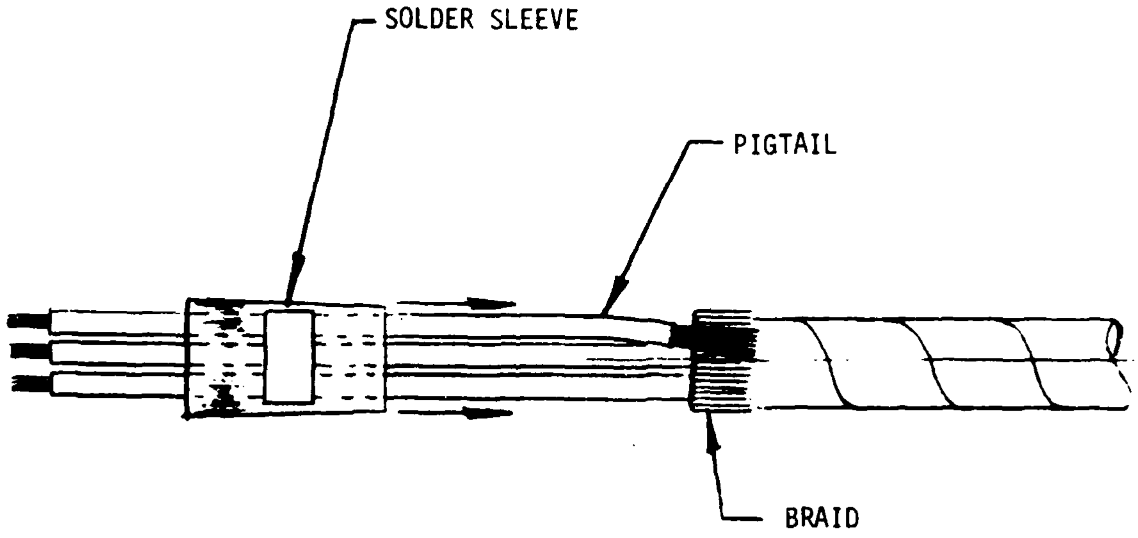


(B) FINISHED CRIMP



(C) SECTION THRU FINISHED CRIMP

FIGURE 10-8 TYPICAL CABLE COMPONENTS PREPARATION FOR INSTALLATION OF SHIELD TERMINAL



EXPLODED VIEW

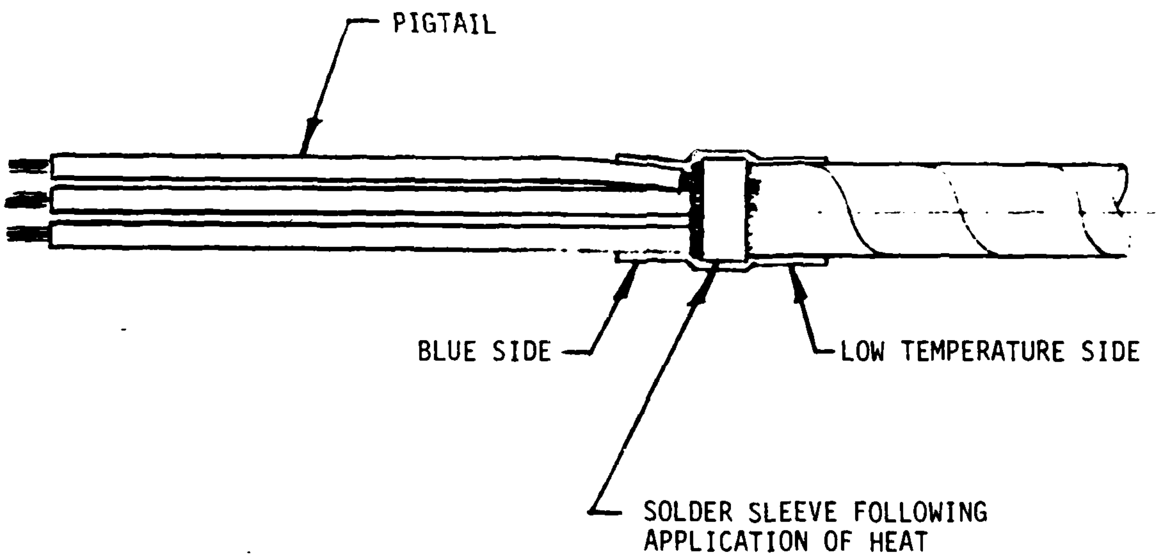


FIGURE 10-9 APPLYING THE SHIELD SOLDER SLEEVE

10.6.2 (Continued)

NOTE

RIGHT ANGLE PLUGS REQUIRE SPECIAL ATTENTION IN OBTAINING PROPER CONDUCTOR LENGTHS. STEPS 6 THROUGH 8 APPLY. THESE LENGTHS WILL VARY DEPENDING ON THEIR RELATIVE POSITION IN THE PLUG INSULATOR. FIGURE 10-10 ILLUSTRATES THE TECHNIQUE.

6. Use the prepot mold as a cutting fixture to determine the required conductor length. The conductors should be inserted into their corresponding insulator holes and properly laid out in the mold cavity.
7. Trim the conductors as specified in Figure 10-10 and remove the cable from the prepot mold. Now cut the conductors to the "X" dimension specified in the figure.
8. Remove the required length of conductor insulation with the thermal stripping tool.

10.6.3 <u>Soldering Cable Conductor to Contacts</u>

1. Cleanliness is of primary importance in making a good soldered joint. Use a brush and trichloroethane solvent to remove sealing compounds, dirt, oil, or grease from the conductor strands, shields, and socket contacts. Use an electric soldering iron rated from 60 to 100 watts. Maintain the iron at 600^{o}F. Use a resin-core solder (60% tin, 39.75% lead, 0.25% antimony) in accordance with QQ-S-571.

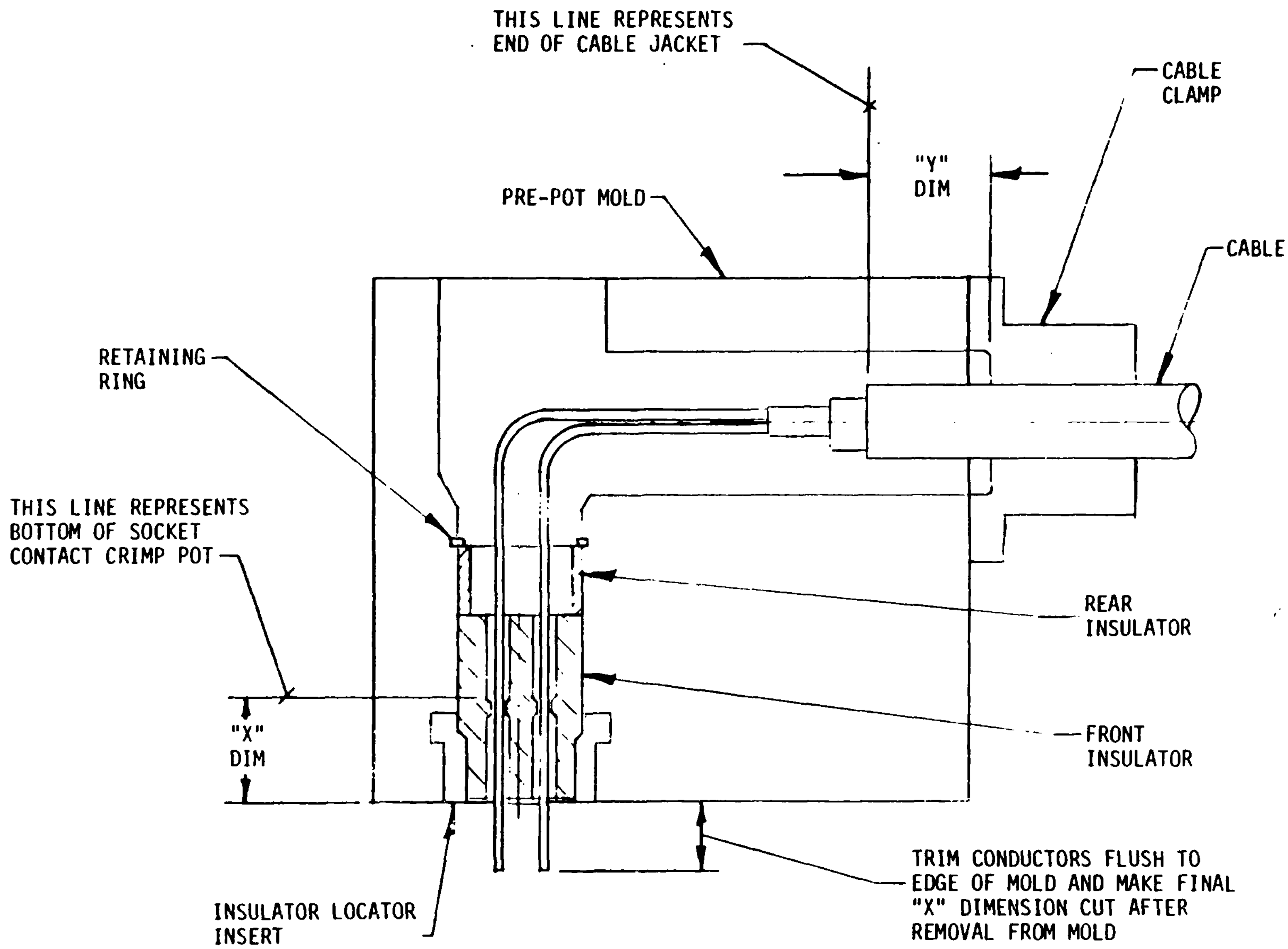


FIGURE 10-10 METHOD OF DETERMINING CONDUCTOR LENGTHS OF RIGHT ANGLE PLUGS

10.6.3 (Continued)

NOTE

USE A 250-300 WATT SOLDERING IRON FOR THE THE NO. 10 AND LARGER AWG CONDUCTORS.

2. Twist the conductor strands tight.

3. Tin the conductors and shield by rolling them on a hot iron and applying a little solder.

4. Hold the socket contacts with pliers or fixture and pretin the solder pot by loading the pot with solder and slushing out while the solder is still molten.

5. Place the cable in a vise and fit the conductors where applicable, through their proper holes in the rear insulator. Fit the conductor into the solder pot of the socket contact.

6. Place the soldering iron across the back of the solder pot and apply solder to the cutaway portion of the solder pot and the exposed wire.

7. Immediately remove the iron and do not move the wire. If the wire is moved at this point, a cold soldered joint can result.

8. Solder should cover the wire, but the wire contour should still be visible. If the solder does not cover the wire, add more. However, too much solder in the cup will run out and prevent slipping the middle or rear insulator back over the socket contacts. This must be avoided. Excess solder may be removed from the outside of the socket contact with a knife.

10.6.3 (Continued)

Wipe all socket contacts and solder pots with solvent (preferably alcohol) to ensure cleanliness and to remove all traces of flux.

NOTE

CHECK SOCKET CONTACT O-RINGS BEFORE AND AFTER INSTALLATION.

10.6.4 Crimping Cable Conductors to Contacts

1. Select the proper contact to suit the conductors and the corresponding positioner for the M 22520/1-01, crimping tool.
2. Inspect the socket contacts for damage. Discard damaged contacts.
3. Insert the appropriate positioner into the crimping tool and lock in place.
4. With the crimping tool handles squeezed together to the stop, insert the go gage into the positioner. It should enter freely. With the crimping tool handles in the same position, the no-go gage should not enter the opening between the crimping tool indentors.
5. Cycle the crimping tool to be sure the crimp indentors are open, ready to accept the contact.
6. Insert the stripped conductors into the contact crimp barrel. Be sure to insert the wire to the bottom of the barrel. The conductor should be visible in the inspection hole at the bottom of the barrel.

10.6.4 (Continued)

7. With the conductor in the crimp barrel, insert the front end of the contact through the indentor opening into the positioner.

8. Squeeze the tool handles together until the positive stop is reached. The tool will then release the return to the fully open position. Remove the crimped contact from the positioner.

10.6.5 Plug Shell Preparation

1. Check the plug assembly prior to starting this phase of the procedure.

2. Remove the plug O-ring, nylon thrust washer, insulator retaining ring, insulators, protective cap, contacts and coupling ring from the plug shell and store them in a clean, closed container until ready for assembly.

NOTE

CHECK THE O-RING GROOVE AGAIN FOR NICKS AND SCRATCHES.

3. Vapor degrease the plug shell in trichloroethylene or trichloroethane. Total elapsed time between initial vapor degreasing and sandblasting should not exceed 24 hours. If this period is exceeded, degrease the plug shell again.

10.6.5 (Continued)

4. Mask all areas of the plug shell on the outside surface to the distance shown in Figure 10-11. Protect the insulator retaining ring groove with masking tape, rubber stopper, or other suitable method.

5. Sandblast the unmasked area with a clean, dry 60 to 100 mesh silica sand or aluminum oxide abrasive. Use new grit if cleanliness and dryness are questionable. Blow off residual grit and remove the masking tape from the shell.

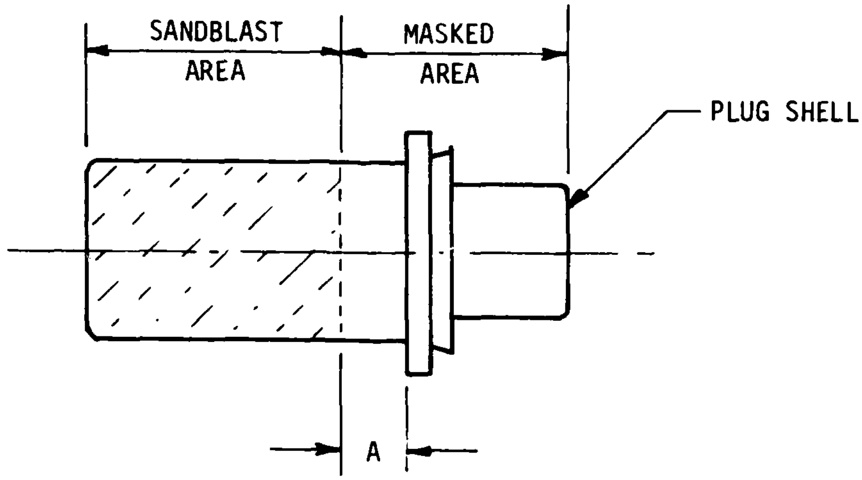
NOTE

SANDBLASTING APPARATUS SHALL PROVIDE AN AIR NOZZLE WITHIN THE UNIT TO ALLOW BLOWING THE SANDBLASTED COMPONENTS FREE OF RESIDUAL GRIT. THE AIR MUST BE FILTERED AND DRY. INSPECT AND REPLACE FILTER AT APPROPRIATE INTERVALS TO AVOID CONTAMINATION.

6. Vapor degrease the shell again and also the coupling ring to prevent the latter from contaminating the prepared shell surface. Total elapsed time between sandblasting and final degreasing should not exceed four hours. If this period is exceeded, sandblast the shell once again as noted in the above steps.

NOTE

DO NOT TOUCH THE PREPARED AREA OF THE PLUG SHELL. IF THIS HAPPENS, THE PLUG SHELL MUST BE VAPOR DEGREASED ONCE AGAIN.



PLUG SIZE	DIMENSION A (Inch)
3 No. 16	5/16
5 No. 16	5/16
9 No. 16	5/16
14 No. 16	5/16
24 No. 16	7/16
3 No. 12	5/16
3 No. 8	7/16
3 No. 4	7/16
3/8 - 3/12	7/16
3 No. 0	1/2

FIGURE 10-11 MIL-C-24217 PLUG SHELL SANDBLAST AREA

10.6.5 (Continued)

7. Assemble the coupling ring on the plug shell and secure the ring against the shoulder of the shell by screwing the coupling ring to plug spacer piece of the mold. This will prevent the coupling ring from interfering with the subsequent application of the metal primer and adhesive.

NOTE

PLACE THE CLEAN ASSEMBLY IN A SEALED CONTAINER SO AS NOT TO CONTAMINATE THE PLUG.

10.6.6 Prepot Molding

10.6.6.1 *Preparation of Plugs with Solder Cup Contacts*

1. Roughen the cable jacket "Y" inches from the cable jacket termination as in Figure 10-10 for right angle plugs. Roughen the jacket 1/2 inch from the termination on straight plugs.
2. Wipe the roughened jacket area with methyl ethyl ketone (MEK).
3. Apply a coat of neoprene cable primer per Table 10-2. Allow the primer to dry a minimum of 1/2 hour and a maximum of 4 hours.
4. Brush on a light coat of DC-20 (diluted 3 to 1 in hexane) to the prepot mold cavity and to the front insulator locator insert.

NOTE

DO NOT USE AEROSOL SPRAY RELEASE AGENTS.

10.6.6.1 (Continued)

5. For plugs with solder type contacts, draw down the previously installed rear insulator against the shoulder on the contacts. See that the O-rings are installed on the contacts and place the front insulator in its correct position over the contacts.

6. Assemble the insulator assembly inside the insulator locator insert and place it inside the prepot mold.

NOTE

DO NOT KINK CONDUCTOR AFTER INSTALLATION IN THE FRONT INSULATOR.

7. Clamp the cable in place.

8. Place the retaining ring in position (for right angle plugs only).

9. Tie with lacing tape where necessary to keep the conductor bundle centered in the prepot mold cavity.

10. Close the mold.

10.6.6.2 *Preparation of Plugs with Crimp Contacts*

1. Slip the rear insulator over the conductors.

2. Push the crimp type contacts into the front insulator by hand or, if necessary, with Bendix tool part no. 11-7736 (or equivalent). Insert a socket contact in each front insulator cavity; even if the contact is not wired to cable, crimp a 16 AWG conductor to each contact. The conductor length should extend approximately 1/16 inch above the RTV sealant.

10.6.6.2 (Continued)

NOTE

DO NOT KINK CONDUCTOR AFTER INSTALLATION IN THE FRONT INSULATOR.

3. Seal the rear of the front insulator with approximately 1/16 inch thick layer of GE RTV 112 or Dow Corning Silastic 732 silicone sealant.

4. Draw down the rear insulator and allow the sealed insulator assembly to cure in a vertical position for a minimum of 45 minutes at room temperature. This is best done by clamping the cable in a laboratory clamp and allowing the insulator assembly to hang vertically below the clamp.

5. Roughen the cable jacket "Y" inches (see Figure 10-10) from the jacket termination on right angle plugs. Roughen the jacket 1/2 inch from the jacket termination on straight plugs. Blow residual grit out of rear insulator with clean, dry air.

6. Wipe the roughened jacket area with methyl ethyl ketone (MEK).

7. Apply a coat of the neoprene cable primer per Table 10-2. Allow the primer to dry a minimum of 1/2 hour and a maximum of 4 hours.

8. Brush on a light coat of DC-20 (diluted 3 to 1 in hexane) to the prepot mold cavity and to the front locator insert.

NOTE

DO NOT USE AEROSOL SPRAY RELEASE AGENTS.

10.6.6.2 (Continued)

9. Assemble the insulator assembly inside the prepot mold.
10. Clamp the cable in place.
11. Place the retaining ring in position (for right angle plugs only).
12. Tie with lacing tape where necessary to keep the conductor bundle centered in the prepot mold cavity.
13. Close the mold.

10.6.6.3 *Molding Plug Prepot*

1. Preheat the prepot mold to 180°F in an oven.
2. Fill the mold cavity with the polyurethane compound specified in Table 10-2. Inject the compound in a manner to prevent air voids. Always fill from the lowest possible point of the cavity.
3. Cure the polyurethane at 180°F for a minimum of seven hours. A Hoedra, Inc., portable heating platen may also be used for this curing process instead of the standard type ovens.
4. Carefully remove the prepotted insulator assembly from the prepot mold when fully cured.

10.6.7 Cable Boot Molding

1. Secure the prepotted insulator assembly within the previously cleaned plug shell. Do not touch the vapor-degreased plug shell. In straight type plugs, no retaining ring is used. On right angle plugs the retaining ring is used to secure the insulator assembly

10.6.7 (Continued)

in the shell. Screw the mold plug spacer to the coupling ring. Screw the insulator spacer into the mold plug spacer so it supports the front insulator.

2. Roughen the cable jacket with a coarse abrasive cloth to a distance where the molded boot will end.

3. Lightly wipe the roughened area of the cable jacket with trichloroethylene or trichloroethane.

4. Wipe the polyurethane prepot with MEK.

5. Apply a uniform coat of Thixon P-4 primer to the shell within 4 hours of final vapor degreasing. The primer must be thoroughly stirred before using. Allow the primer to dry completely (minimum of 1/2 hour and maximum of 4 hours).

6. Mix one part by weight of PAC-136A (accelerator) to 36 parts by weight of PAC-136B (adhesive) to make the PAC-136.

7. Apply a uniform coat of PAC-136 to the roughened area of the cable jacket. Allow to dry for 1/2 hour minimum, 4 hours maximum.

8. Apply a uniform coat of CHEMLOK 220 to the surface of the polyurethane prepot. Allow the adhesive to dry for a minimum of 1/2 hour and a maximum of 4 hours.

9. Apply a uniform coat of Thixon NM-2 adhesive to the shell. Allow the adhesive to dry thoroughly (minimum of 1/2 hour and maximum of 4 hours).

10.6.7 (Continued)

10. Freshen on the rubber mill and sheet out the neoprene molding compound to a thickness of 1/8 inch to 3/16 inch.

11. Place the freshened neoprene sheet on a polyethylene film to prevent surface contamination.

12. Select a template from those listed in Figure 10-12 and cut pieces of compound to fit into the cavity of each mold half.

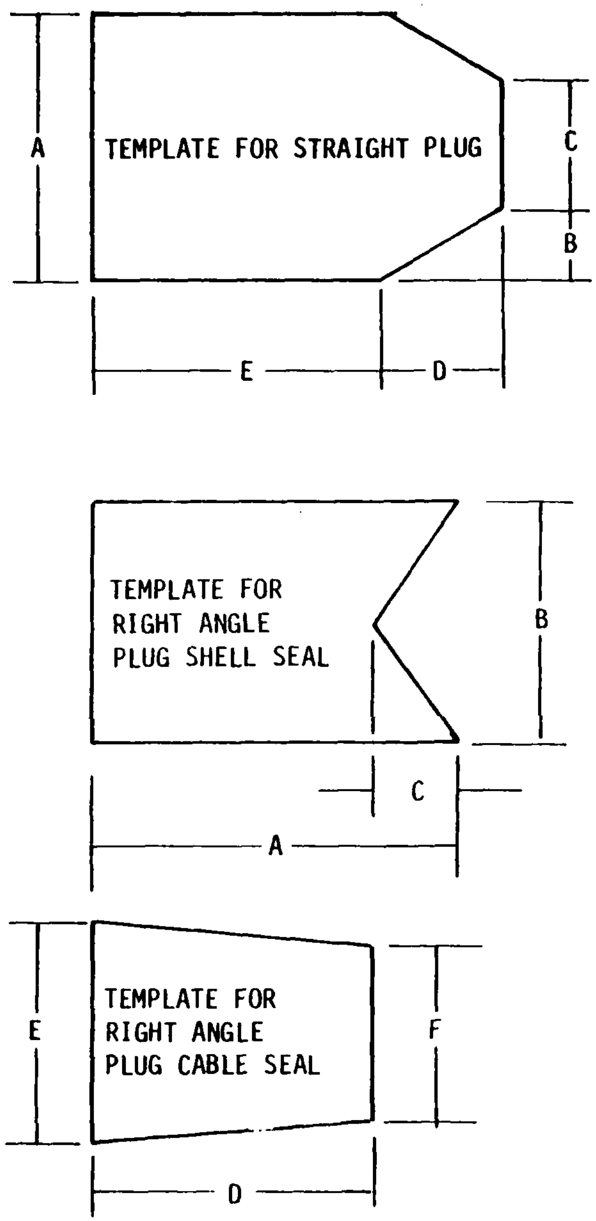
13. Obtain the proper mold for the cable type and plug size being molded.

14. Position neoprene compound in each mold half. Build up from the middle of each cavity so that excess compound flows out toward the parting line without trapping air. Fill the mold cavities fairly even with the mold parting lines. Right angle mold cavities must be carefully packed to avoid air entrapment.

15. Place the plug/cable assembly in the bottom half of the mold and attach the mold cable clamp.

16. Assemble the mold halves. Place the mold between the platens of a molding press which has been previously heated to 305-310^{o}F.

17. Apply the load to the mold slowly. The press ram should not be pumped above one-half the molding load listed in Table 10-4, until the mold halves are 1/16 inch from being fully closed. At this point, pump the ram load in increments up to the full molding load, releasing the ram after each increment. This pumping action, called bumping the mold reduces possible molding defects such as poor knitting, air masks, etc.



PLUG TYPE AND SIZE	Dimensions (Inches)					
	A	B	C	D	E	F
3 NO. 16, STRAIGHT	1-1/2	1/2	1/2	1	1-1/4	-
3 NO. 16, RT. ANGLE	2	2-1/4	1/2	2-3/4	1-3/4	1
5 NO. 16, STRAIGHT	2	5/8	3/4	1-3/4	2	-
5 NO. 16, RT. ANGLE	2-3/8	2-3/8	5/8	3	2	1
9 NO. 16, STRAIGHT	2-1/2	7/8	3/4	2-1/4	2	-
9 NO. 16, RT. ANGLE	2-3/4	2-5/8	7/8	4	2-3/8	1-3/8
14 NO. 16, STRAIGHT	3-1/8	7/8	7/8	2-1/4	2-1/4	-
14 NO. 16, RT. ANGLE	3-3/8	3-1/4	1-1/4	4	2-3/4	1-5/8
24 NO. 16, STRAIGHT	3-3/4	7/8	1-1/4	2-5/8	2-3/4	-
24 NO. 16, RT. ANGLE	4	3-1/2	1-3/8	4-3/8	3-1/8	2
3 NO. 8 WITH 3 NO. 12 SIZE CONTACT, STRAIGHT	4	1-1/8	1-3/4	3-1/4	2-1/2	-
3 NO. 8 WITH 3 NO. 12 SIZE CONTACT, RT. ANGLE	4	3-1/2	1-3/8	4-3/8	3-1/8	2
3 NO. 8, STRAIGHT	3-1/4	1	1-1/4	2-5/8	2-1/4	-
3 NO. 8, RT. ANGLE	3-1/2	3-1/4	1	4	2-3/4	1-1/2
3 NO. 4, STRAIGHT	4	1-3/8	1-3/4	3-1/4	2-1/2	-
3 NO. 0 RT. ANGLE	5-1/2	2-3/4	1	6	3-1/4	3-1/4

FIGURE 10-12 TEMPLATE DIMENSIONS FOR NEOPRENE MOLDING

TABLE 10-4

PLUG MOLDING PRESS DATA

PLUG SIZE	PLUG TYPE	PLATENT LOAD (lbs.)
3 No. 16	Straight	2,000
3 No. 16	Right Angle	2,000
3 No. 16	In-Line	3,000
5 No. 16	Straight	3,000
5 No. 16	Right Angle	3,000
9 No. 16	Straight	4,000
9 No. 16	Right Angle	4,000
9 No. 16	In-Line	5,000
14 No. 16	Straight	5,000
14 No. 16	Right Angle	5,000
24 No. 16	Straight	10,000
3 No. 12	Straight	4,000
3 No. 8	Straight	4,000
3 No. 8	Right Angle	8,000
3 No. 4	Straight	8,000
3 No. 0	Right Angle	12,000
3/8-3/12	Straight	8,000
Grounding	Cable	3,000
3/8-3/12	Right Angle	10,000
24 No. 16	Right Angle	10,000

10.6.7 (Continued)

18. Mold at the specified molding load and temperature (300-305°F) for one hour.

19. After curing, cool the mold to 100°F before removing the molded connector.

20. Remove the mold cable clamp.

21. Place mold jacking screws in the threaded holes over the dowel pins and jack the top half of the mold off the bottom half.

22. Be careful not to tear the molded assembly when removing it from the bottom half of the mold.

NOTE

DO NOT PULL EXCESSIVELY TO REMOVE THE MOLDED ASSEMBLY. CAREFUL PRYING WILL RELEASE THE PLUG.

23. Remove the plug spacer and mold insulator spacer.

24. Trim the neoprene flash from the molded plug assembly. If the coupling ring is bound by cured neoprene molding compound, inject a few drops of DC-20 silicone release agent on both sides of the ring to facilitate its release.

25. Install the split nylon thrust washer.

26. Make sure the plug shell's dovetail O-ring groove is clean. Apply a thin film of DC-55 or Cosmolube 615 lubricant to the plug shell O-ring and place it in the groove.

10.6.7 (Continued)

27. Install the non-ferrous metal plug protective cap. Figure 10-13 depicts a neoprene rubber molded, polyurethane prepotted MIL-C-24217 plug assembly with protective cap installed.

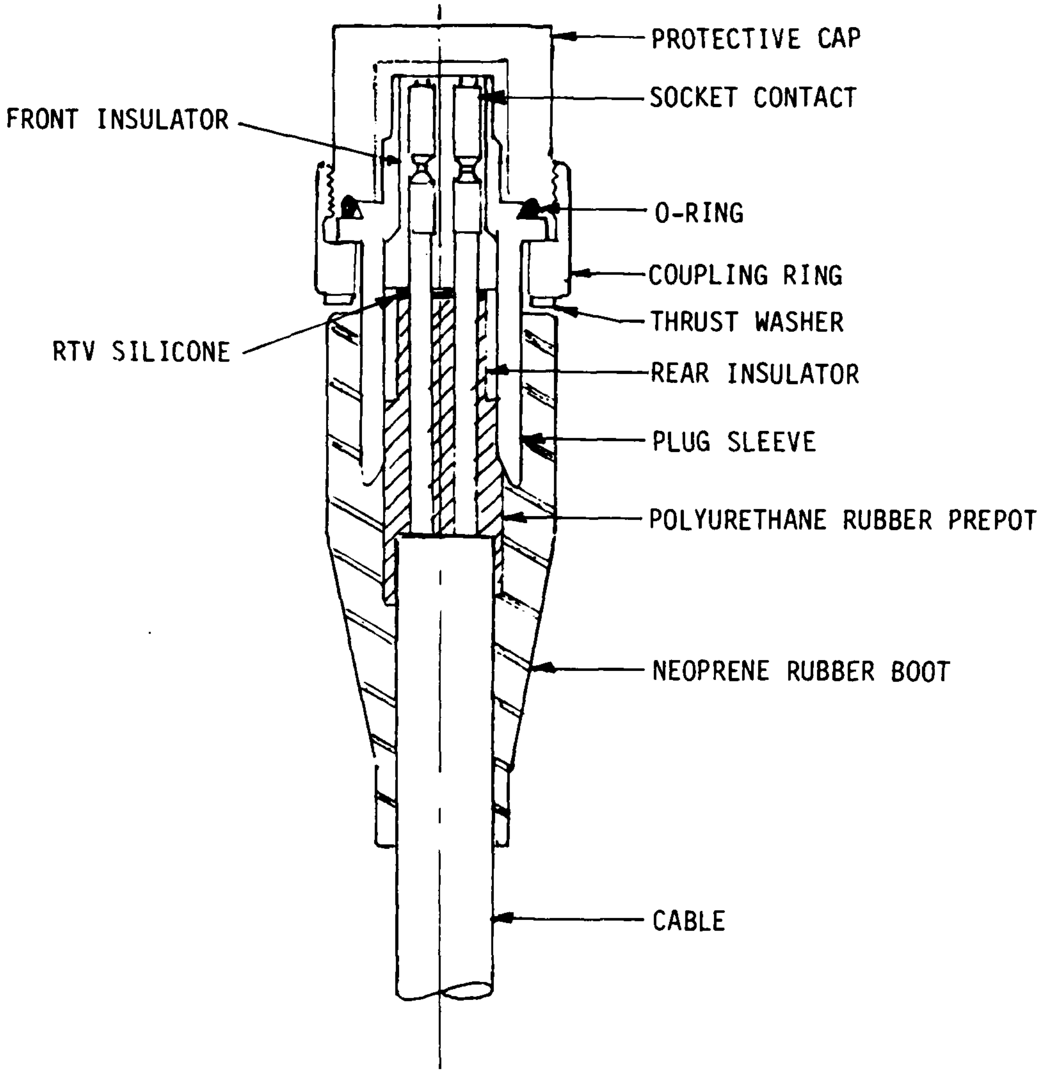


FIGURE 10-13 NEOPRENE MOLDED MIL-C-24217 PLUG ASSEMBLY

10.7 Preparation of Epoxy Prepotting Material

At hydrostatic cycling pressures (2000 cycles) in excess of 2000 psi, it has been found necessary to prepot the connectors with epoxy to prevent conductor kinking and subsequent breaking inside the connector. The testing conducted on the DSRV deep submergence vehicles revealed this requirement when the connectors were subjected to 4000 psi hydrostatic pressure tests. More recent connector tests conducted by the Navy indicate that the epoxy prepot is required at pressures as low as 2000 psi. The following is an epoxy compound successfully used at Electric Boat Division for prepotting connectors. It should be noted that many other formulations are available and have been successfully applied for similar applications. The following materials are required to prepot four plug connectors.

1. Sonite 41 hardener for epoxy resins - 20 grams
   Smooth-On Manufacturing Company
   572 Communipaw Avenue
   Jersey City, NJ 07304

2. EPON 826 Resin - 100 grams
   Shell Chemical Company
   113 W. 52nd Street
   New York, NY 10019

   OR

   Miller-Stephenson Chemical Co., Inc
   Sugar Hollow Road
   Danbury, CT 06810

10.7 (Cont'd.)

3. H-55 hardener - 3 grams

Allied Resin Corporation
Weymouth Industrial Park
East Weymouth, MA 02189

Heat the Sonite 41 in an oven at 130°F to 150°F until liquified. While the Sonite is still liquid, mix in the EPON 826 and the H-55. After the epoxy is thoroughly mixed, vacuum deaerate at 29 ±5 inches of mercury (equivalent) for ten to fifteen minutes. The pot life of the epoxy is two hours.

The curing time temperature sequence for epoxy prepotting casting is as follows:

1. 2 hours at 130°F ±5°.
2. 2 hours at 170°F ±5°.
3. 2 hours at 212°F ±5°.
4. 1 hour at 280°F ±5°.

The following commercial compound can also be used to prepot the receptacles:

Stycast 2651 with Catalyst 11

Emerson and Cummings, Inc.
Canton, MA 02021

The manufacturer's mixing and curing instructions must be closely adhered to when using this compound.

10.8 Polyurethane Rubber Molding MIL-C-24217 Plugs

MIL-C-24217 connectors are also wired and molded with polyurethane in accordance with Mare Island Naval Shipyard prepared procedures for the DSV 3 and 4. The procedures are detailed in Reference 10-7. The following procedures have been extracted from this document.

10.8.1 Cable Preparation

Prepare the cable for molding in accordance with the method that provides the best adhesion results for the particular jacket material. Preparation should be done just prior to encapsulation.

10.8.1.1 *Neoprene* - To obtain good adhesion to neoprene insulation, the surface should be abraded with a suitable abrasive to remove grease, oil, wax, or mold release. Remove rubber particles by washing with clean MEK. Apply a liberal coat of PR-1523M to the abraded cable jacket by brush and allow to dry for approximately 30 minutes at room temperature. After 30 minutes drying time, blot off excess PR-1523M, If the primed surface becomes contaminated or encapsulation is not accomplished within 4 hours after application of PR-1523M, abrade the primed surface and repeat the priming procedure.

NOTE

PR-1523M IS HYGROSCOPIC AND MUST BE KEPT FREE OF MOISTURE. WHEN PR-1523M HYDROLYZES, A DARK GRAINY PRECIPITATE IS FORMED DECREASING THE PRIMER USEFULLNESS. MATERIAL CONTAINING PRECIPITATE SHOULD BE TESTED TO DETERMINE THAT ADHESION IS SATISFACTORY BEFORE USING.

10.8.1.2 *Polyvinyl Chloride* - To obtain good adhesion to polyvinyl chloride insulation, the surface should be made tacky with methyl ethyl ketone. The use of a primer may be necessary with some formulations of polyvinyl chloride. Should a primer be required, then apply a thin coat of PR-1543 to the tackified surface by brush and allow to dry 30 minutes at room temperature. If primed surfaces become contaminated before potting or molding, buff primed surface with a suitable abrasive and reapply a thin coat of PR-1523M. It should be noted that there are many formulations of polyvinyl chloride. Therefore, it is suggested that before production quantities of PR-1543 are ordered, tests be made to determine the adhesive strength of PR-1543/PR-1547 system to the polyvinyl chloride in question.

NOTE

PR-1523M IS HYGROSCOPIC AND MUST BE KEPT FREE OF MOISTURE. WHEN PR-1523M HYDROLYZES, A DARK GRAINY PRECIPITATE IF FORMED DECREASING THE PRIMER USEFULLNESS.

10.8.1.3 *Polyurethane Cable Jacket* - Abrade polyurethane jacket with a suitable abrasive. Remove rubber particles by washing with clean MEK. Encapsulation should be done as soon as possible.

10.8.1.4 *Hypalon Cable Jacket* - Prepare Hypalon jacket using procedure for polyvinyl chloride cable jacket.

10.8.2 Connector Preparation

Disassemble the connector by removing the plug O-ring, nylon thrust washer, insulators, protective cap, contacts and coupling ring from the plug shell. Inspect the O-ring groove and matching surface. Scratches and gouges in this area shall be cause for rejection.

1. Vapor degrease the connector shell to remove all oil and grease prior to sandblasting. Washing with MEK is satisfactory if a vapor degreaser is not available.

2. Protect the surfaces that are not to be sandblasted with masking tape or suitable masking jigs. Sandblast the surfaces that are to be bonded with 60 to 100 mesh abrasive garnet. A progressive sandblast with the first blast removing the surface contaminants and a secondary blast using clean dry abrasive garnet to sandblast to white metal is recommended. The sandblast equipment should be supplied with filtered, oil-and-water-free air.

3. Remove masking tape or masking jig, wash sandblasted area of sleeve with clean MEK. Use clean washed rags or lint-free paper towels. Do not use KIMWIPES or other silicone treated towels.

NOTE

PROTECTIVE SYNTHETIC RUBBER OR PLASTIC GLOVES SHALL BE WORN. DO NOT TOUCH SANDBLASTED SURFACES WITH BARE HANDS OR ALLOW TO BE CONTAMINATED WITH MOISTURE, OIL OR GREASE.

10.8.2 (Continued)

4. Inspect the sandblasted surface prior to painting, for any contamination. Prime sandblasted surface within 30 minutes of sandblasting with PR-420. Record lot number and date. Any crystalline formation in Part "A" of PR-420 shall be cause for rejection. Part "B" cakes very badly and must be homogenized before mixing with Part "A". Stir with a stainless steel spatula and shake on a paint shaker until completely dispersed. Add Part "A" and shake another 15 minutes. Do not leave the can uncovered as this will allow the solvent to evaporate and allow reaction of the primer with moisture in the air. After using the primer, purge the can with dry nitrogen and reseal. Use complete kits when mixing, do not try proportioning the kits. Use the size kit that can be used within 4 hours. Dispose of any unused primer after 4 hours.

5. Apply one brush coat of PR-420 to the metal surfaces of the sleeve to be encapsulated. The primer should be opaque, approximately 2 to 3 mils thick. Allow the primer to dry for one hour at room temperature. If the surface becomes contaminated or encapsulation has not been done within 4 hours after priming, Steps 2 through 5 shall be repeated.

10.8.3 <u>Wiring Preparation</u>

Trim conductors and shields to proper length during assembly. Remove 5/16 inch insulation from each conductor. In cases where the conductors contain a water-blocking material, it will be necessary to untwist the conductor strands and remove the sealing material from the strands. Wash with MEK or trichloroethylene solvent and retwist the conductor strands.

10.8.3.1 Solder the socket contacts to the conductors using the following method:

NOTE

USE ONLY ROSIN CORE SOLDER MEETING THE REQUIREMENTS OF QQ-S-571.

1. Tin the conductors and the ends of the shields by placing them on a clean pre-tinned soldering iron, apply solder to conductor or shield and allow it to flow through to the soldering iron. Excess solder will flow on to the iron.

2. Hold the socket contact with pliers or place on a socket holding jig and pre-tin the solder pot of the contact by loading the pot with solder. Slush out the excess solder while it is still molten.

3. Hang the cable so that the conductors are in a downward position and fit the conductor into the solder pot and fit the conductor into the solder pot and the exposed wire.

4. Place the hot soldering iron across the back of the solder pot and apply solder to the cutaway portion of the solder pot and the exposed wire.

5. Immediately remove the iron, but do not move the wire. At this stage, a cold soldered joint (frosted appearance) could result. Reheat solder joint if this happens.

6. Solder should cover the wire, but the wire contour should still be visible. If the solder does not cover the wire, add more. If too much solder has been placed in the solder pot, it will run out during the soldering operation. Remove any excess solder from the outside of the socket contact with a knife. Do not damage contact. If solder flows into the contact area, replace contact.

10.8.3.2 Crimp cable conductors to contacts using the following method:

1. Select the appropriate locating tool for the socket contact. Insert the locator into the crimping tool and lock in place. Test operation of the crimping tool with the go-no-go gages.

2. Insert the stripped conductors into the contact crimp barrel. Be sure to insert the wire to the bottom of the barrel. The conductor should be visible in the inspection hole at the bottom of the barrel.

3. With the conductor in the crimp barrel, insert the front end of the contact through the indentor opening into the positioner.

4. Squeeze the tool handles together until the positive stop is reached. The tool will then release the return to the fully open position. Remove the crimped contact from the positioner.

Wash conductors and contacts with MEK. Reassemble connector assembly. Install socket contacts with filler wire in all unused positions.

To prevent the polyurethane encapsulant from flowing into the socket contact area, a layer of epoxy approximately 1/16 inch thick shall be applied to the backside of the front insulation around the contacts. Mix and apply Epibond 1217 or equivalent fast curing 2 part epoxy according to manufacturer's instructions. Allow to cure at room temperature approximately 30 minutes. Prime exposed metal contacts with PR-420 primer. Prime conductor insulation with applicable primer.

10.8.4 Plug Molding Procedure

1. The mold surfaces shall be covered with a dry, non-transferrable form of mold release. Mold releases which have given good results include baked on teflon coating or a sprayed on coating such as NOSTICKENSTOFF.

2. Assemble the mold around the cable and connector shell. Insure that the mold fits snugly around the teflon seal on the connector shell. Clamp the assembly in an upright position. Install mold between the mold heaters. To avoid cable gassing, the mold temperature should be maintained at 100° - $110^{\circ}F$ until the polyurethane sets up, approximately 2 hours, then the mold temperature may be raised to $180^{\circ}F$.

3. The mixing ratio of PR-1547 is 32 Parts "A" to 100 Parts "B" by weight or by volume.

NOTE

PART "A" MAY PARTIALLY CRYSTALLIZE AT ROOM TEMPERATURE. WHENEVER THIS CONDITION IS FOUND, LOOSEN LID AND WARM TO $220^{\circ}F$. DETERMINE THE ACTUAL MATERIAL TEMPERATURE WITH A THERMOMETER. LIQUIFICATION MUST BE COMPLETE, TRACE QUANTITIES OF UNLIQUIFIED PART "A" WILL CAUSE PREMATURE SOLIDIFICATION.

4. Part "A" and Part "B" should be stabilized at 75° to $85^{\circ}F$ before mixing. Place both parts in a clean, dry metal container of twice the volume of the material to be degassed. Mix Part "A" and Part "B" thoroughly with a metal mixing paddle. Do not use wooden paddles or a waxed-lined container for mixing.

10.8.4 (Continued)

WARNING

NEOPRENE OR PLASTIC GLOVES MUST BE WORN. ADEQUATE VENTILATION IS REQUIRED.

Place the container with mixed material in a vacuum chamber and degas at a pressure of five (5) millimeters of mercury or less. Degas for at least ten minutes or until the bubbling subsides. Transfer the material to the 6-fluid ounce size polyethylene SEMCO or Pyles sealant gun cartridge(s) plugged either with 1/4 NPT pipe plug(s) or No. 5 size caplug polyethylene thread protector(s). If any air is entrapped during the filling of the cartridge(s), degas the cartridge(s) at a pressure of less than five (5) millimeters of mercury for two (2) minutes. If extra care is taken when filling the cartridge(s) with degassed material such as flowing the material down the side of the cartridge(s), the material may not need to be degassed in the cartridge(s). Position the plungers in the cartridge(s) immediately and insert a metal thermometer or screwdriver along the side of each cartridge to form a vent. Push in the plunger until all air is displaced between it and the compound.

NOTE

AFTER MIXING OF PARTS "A" AND "B", SUBSEQUENT OPERATIONS SHOULD BE ACCOMPLISHED AS QUICKLY AS POSSIBLE TO MINIMIZE THE REDUCTION OF APPLICATION LIFE. THE MIXED MATERIAL SHOULD BE USED WITHIN TWO HOURS AFTER PREPARATION.

10.8.4 (Continued)

NOTE

THE STORAGE LIFE OF PR-420 IS AT LEAST ONE YEAR WHEN STORED AT TEMPERATURES BELOW 80°F IN THE ORIGINAL UNOPENED CONTAINER.

STORAGE LIFE OF THE TWO PART POLYURETHANE MOLDING COMPOUND IS SIX (6) MONTHS WHEN STORED AT TEMPERATURES BELOW 80°F IN ORIGINAL UNOPENED CONTAINERS. ANY CANS OF COMPOUND THAT ARE OVER SIX (6) MONTHS OLD SHALL BE DISCARDED AND NEW MATERIAL OBTAINED.

5. Remove the 1/4 inch pipe plug or caplug from the 6-ounce cartridge of molding compound and attach a plastic nozzle or 1/8 inch pipe nipple and reducing bushing. Attach the pressure sealant gun to the cartridge. Expel any air from the nozzle or pipe nipple before attaching sealing gun to mold. Screw the nozzle of the cartridge into the bottom fill hole of the mold if 1/8 inch pipe nipple and bushing are used. If HOEDRA injection valve is used, screw valve into bottom fill hole of the mold, insert plastic nozzle into valve. Force molding compound into the mold. Continue to force the molding compound into the mold until the compound bleeds out of the vent hole located in the top of the mold. When more than one 6-ounce cartridge of molding compound is required, replace the empty one with a full one being sure to expel any air bubbles and proceed with the filling of the mold as described above, or start with a 12-ounce tube.

10.8.4 (Continued)

6. If the 1/8 inch pipe nipple and bushing are used, the cartridge of molding compound, together with the sealant gun can be left attached to the mold during the curing cycle provided the gun is not required for another operation. In this case, unscrew the nozzle slowly from the fill hole keeping pressure on the gun to assure that the fill hole will be filled with compound. Plug the fill hole with the provided 1/8 inch pipe plug. If the HOEDRA injection valve and plastic nozzle are used, simply withdraw sealant gun nozzle from the injection valve keeping pressure on the gun to insure that the valve will be filled with compound.

7. After the polyurethane has set up raise mold assembly to 180°F $\pm$ 5°F. When an urgent need for the mold exists, the encapsulated connector can be removed from the mold after 3 hours at 180°F. The remainder of the cure can be finished in an oven at 180°F. PR-1547 will cure at 75°F, but the resultant physical properties will be lower than when heat cured.

8. After completion of the polyurethane curing and removal of the mold assembly, the flashing should be trimmed from the molded connector and the molded plug inspected for any bubbles and/or imperfections. Small imperfections can be repaired by abrading the surface to remove any mold release or other contaminants, applying more encapsulant, reassembling the mold and curing for another (6) hours at 180°F. Bubbles found in the plug can be repaired by inserting a hypodermic into the bubble, attaching a syringe filled with encapsulating material to the needle and forcing the material into the bubble. Withdraw the needle slowly and continue

10.8.4 (Contined)

to force material in until the bubble is filled. If the material cannot be forced in due to trapped air, insert another hypodermic needle at a different angle to bleed out the trapped air. Small filled bubbles can be allowed to cure at room temperature, larger bubble repairs will be cured by placing the cable in an 180°F oven for six (6) hours.

9. Frozen pre-mixed cartridges can be used as an alternative to the two-part encapsulant where health precautions preclude the mixing. Facilities must be available for storing the cartridges at -20°F or below. Storage life of the pre-mixed cartriges is seven (7) days at -20°F or 14 days at -50°F. Frozen cartridges of PR-1547 shall be thawed as follows. Remove the cartridge from storage and thaw for 45 minutes $\pm$ 5 minutes at 100° $\pm$ 5°F in a heating block or water bath. Thawing of the cartridce in an oven is not recommended since the time required varies with the oven control and air circulation. When thawing frozen cartridges, keep cartridges in an upright position, nozzle end down with caplug in place, to prevent air from entering and being trapped in the compound. After thawing is complete, insert a thin piece of metal or spatula blade between plunger and cartridge wall to the shoulder of the plunger. Then force plunger down to exhaust any air between compound and plunger face. Use thawed cartridge as per Steps 5 through 7. The application life of the thawed cartridge is one (1) hour at 75°F.

Figure 10-14 shows a polyurethane molded MIL-C-24217 plug assembly.

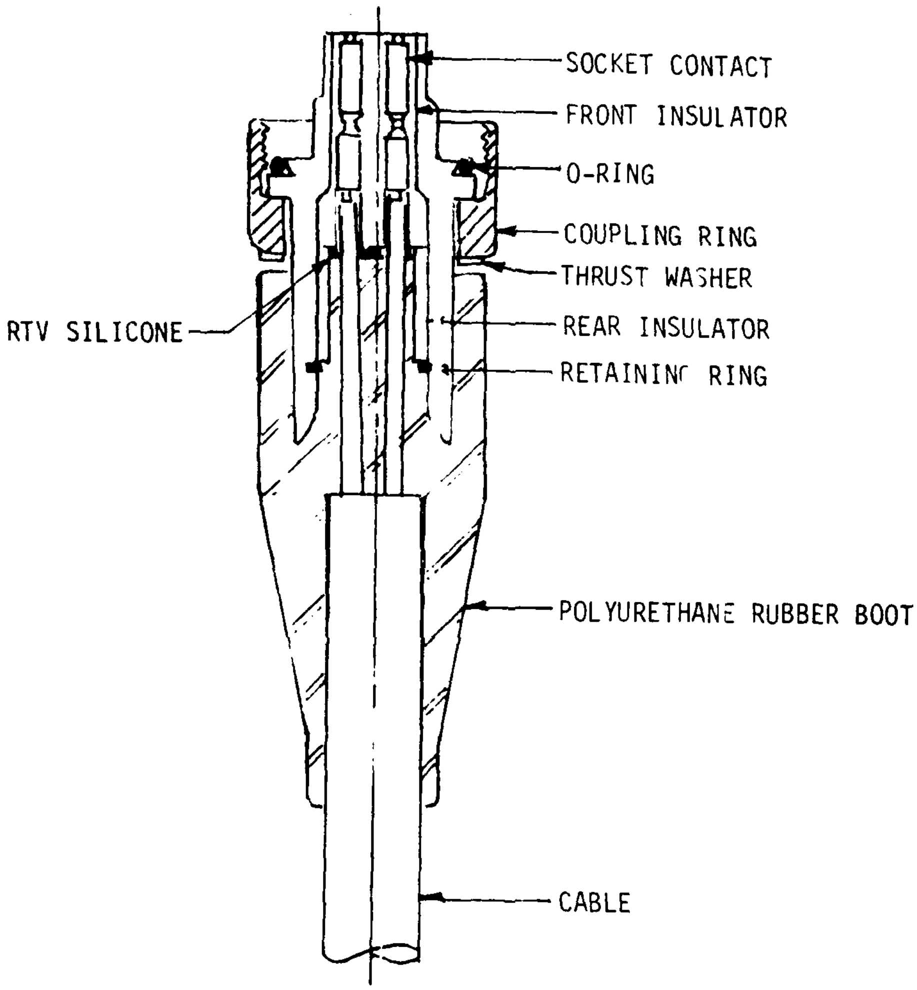


FIGURE 10-14 POLYURETHANE MOLDED MIL-C-24217 PLUG ASSEMBLY

10.9 Noeprene Rubber Molding MIL-C-24231 Plugs

The Naval Underwater Systems Center (NUSC), New London, CT, has developed procedures for neoprene rubber molding MIL-C-24231 plugs. At this time, these procedures have not been formally approved by NAVSEA as they are currently undergoing a service evaluation. The following are excerpts of a molding procedure draft prepared by NUSC in 1979.

10.9.1 Prepotting Plug Insert Assemblies

1. Mix CONAP EN-7 (two part) A and B solutions in well ventilated area. (Ratio by weight is 100 parts of A to 17.5 parts of B). Stir gently with mixing rod to avoid entraining too much air.
2. Place mixture in vacuum chamber for degassing. After chamber is evacuated, bubbles will form and foaming of the mixture will occur. Allow approximately ten minutes for the entrapped air to leave the mixture.
3. Apply a light coat of silicone release agent or equal to the pin plug mold and remove excess.
4. Place the socket contacts on mold pins with the solder cups facing the same way. Note that the plastic sleeving should be pushed over contacts to cover contact springs.
5. Place mold with pins in preheated oven at approximately 180^{o}F.
6. Remove degassed CONAP EN-7 from vacuum chamber and pour into preheated pin mold, being careful not to pour over the pins.
7. Place mold back into oven for curing for 8 to 10 hours.

10.9.1 (Continued)

8. Remove mold from oven, let cool, remove pin plugs from mold and trim excess material. Set aside pin plugs for later use in making up connector.

10.9.2 <u>Plug Sleeve Preparation</u>

1. Prepare Monel plug sleeve for sandblasting by solvent cleaning with trichloroethane or equivalent to remove oil and grease. Then use masking tape to cover areas not to be treated. CAUTION: USE TRICHLOROETHANE UNDER EXHAUST HOOD.
2. Sandblast sleeve with clean 80 grit aluminum oxide at pressure of 60 to 80 psi. Note that inside of sleeve is sandblasted too.
3. Blow grit off with clean, dry, oil-free air. (No cleaning fluids are used). This is important for good bonding.
4. Using a bristle brush apply thin even coat of CHEMLOK 205 to both inside and outside sandblasted portions of sleeve. Let dry for a minimum of 30 minutes. CAUTION: FOLLOW SAFETY PRECAUTIONS FOR CHEMLOK 205.

10.9.2 (Continued)

5. Again using a bristle brush apply thin even coat of Chemlok 220 to inside and outside of sleeve. Let dry for a minimum of 30 minutes. CAUTION: FOLLOW SAFETY PRECAUTIONS FOR CHEMLOK 220.

6. Put primed sleeves aside in clean area, avoiding touching primed areas. Recommend that they be hung by wires inside ventilation hood, or stored in a glass desiccator, or polyethylene bags, etc. (There is no time limit for using primed sleeves if kept clean and dry).

10.9.3 <u>Preparation of Cable</u>

1. Apply cyclohexanone for approximately six inches back of cable end.

2. Scrape "wax" coating off of cable over the area just wet with cyclohexanone with fine-toothed hack saw blade or knife, roughing cable jacket in the process, being careful not to nick or cut cable jacket.

3. Strip outer neoprene jacket back 1-1/8".

4. Strip shield back 1-1/8" and trim close to outer jacket with scissors so no wire strands protrude or dig into inner sheath.

5. Cut back inner insulation 1 inch being careful not to nick black and white inner wires.

6. Strip black and white wires back 1/4" and clean with emery or scrape with knife blade for soldering to pin plug assembly.

10.9.3 (Continued)

7. Slip a 1/2" long piece of Varglas silicone tubing #8 over each wire. Slide back up wire to expose conductors.

8. Obtain CONAP EN-7 prepotted contact assembly, and holding cable in cable fixture, solder black wire to #1 pin and white wire to #2 pin. (See MIL-STD-454 for soldering procedure).

9. After soldering, clean off rosin from solder joints with trichloroethane, dry with clean, dry air. Then slide Varglas tubing over each pin at end of pin plug and wrap individually using Scotch electrical tape #27. CAUTION: USE TRICHLOROETHANE UNDER EXHAUST HOOD.

10. Wash cable again with cyclohexanone to make sure area is clean.

10.9.4 <u>Preparation of Vulcanizing Strips</u>

1. Cut approximately 12 strips of black neoprene tape and lay on polyethylene plastic covered board.

2. Apply coat of cyclohexanone to first side and let dry.

3. When dry, turn over strips and apply coat of cyclohexanone to second side and let dry.

10.9.5 <u>Assembly of Cable to Connector Plug</u>

1. Wrap one strip of neoprene tape over black and white wires to ensure neoprene is in the inside of sleeve. Make sure diameter of wrap is small enought to permit sleeve to slide over it.

10.9.5 (Continued)

2. Slide bronze coupling and Monel sleeve over cable.
3. Align keyways and press pin plug assembly into sleeve. NOTE: USE PAPER TOWEL TO HOLD SLEEVE TO ENSURE CLEANLINESS.
4. Secure pin location adapter in vise.
5. Place cable and plug assembly into adapter, aligning keyways and pins. Then secure with spanner wrench.

10.9.6 Mold Preparation

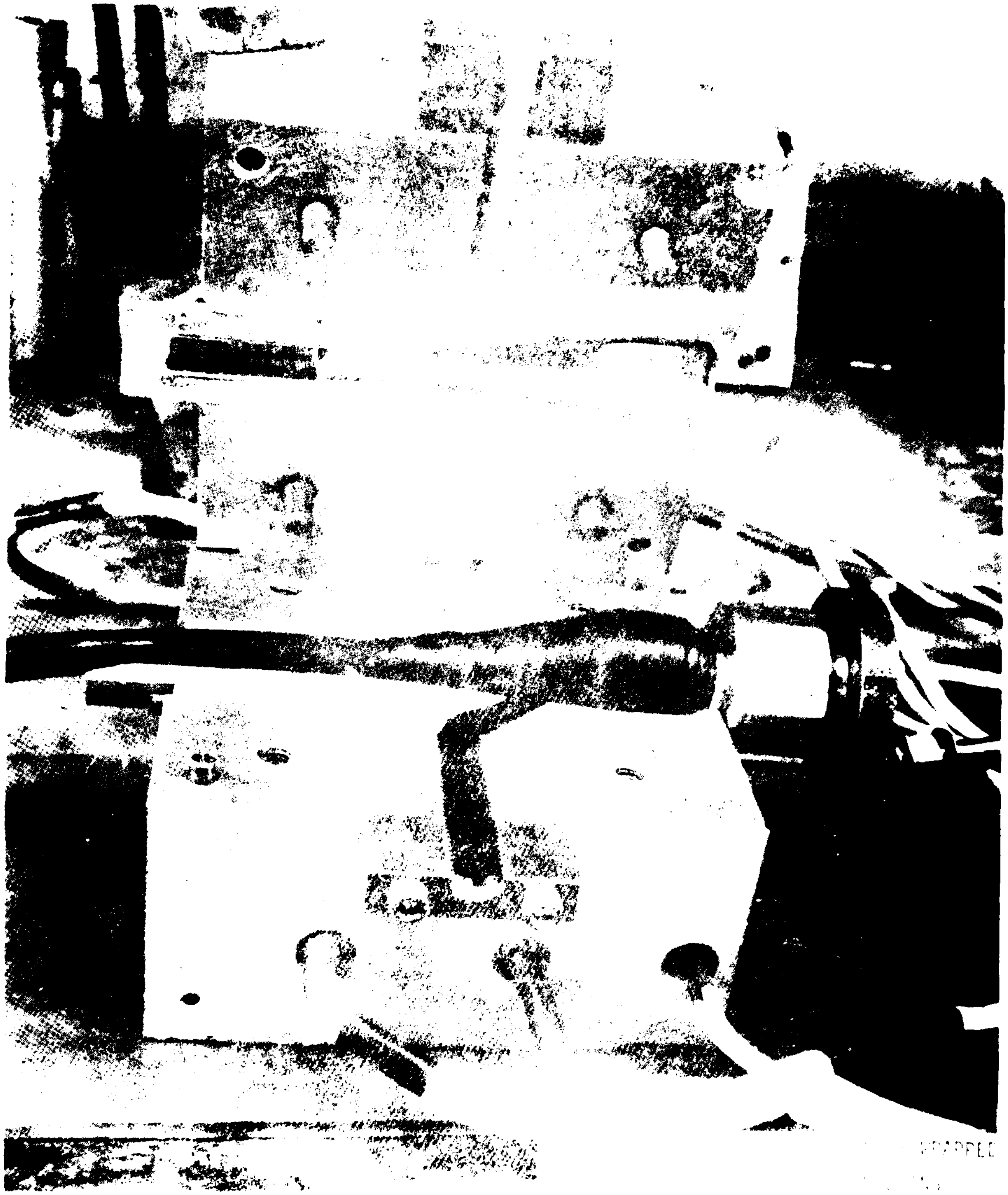
1. Apply a light coat of silicone parting agent or equal on the mold and wipe off excess.
2. Make sure bolts are not stripped and that heaters are in good working order.

10.9.7 Preparation of Cable-Plug Assembly for Molding

1. Insert small neoprene tape slugs into Monel sleeve holes to insure filling of sleeve.
2. Wrap cable-plug assembly with prepared neoprene tape to fit mold. (See Figure 10-15).
3. Lay slugs into bottom half of mold feeder channel.

10.9.8 Molding Operation

1. Secure mold halves together, ensuring that cable is securely clamped. (Approximately .010" squeeze). Place marker on cable to indicate any movement of cable. Add end plate to ensure connector not being pushed out.



10.9.8 (Continued)

2. Start heating mold.

3. When mold temperature reaches approximately 165^{O}F begin feeding rubber slugs into feeder channel. Rate of feed is approximately one revolution of feed screw every two to three seconds. Before temperature reaches 195^{O}F, rubber feeding should be finished with excess rubber coming out of bleeder hole in mold. If not finished feeding rubber, shut off mold to maintain temperature under 195^{O}F.

4. When mold if filled let heat go up to 270^{O}F and maintain that temperature for approximately 1-1/2 hours. Neoprene will be cured at the end of this time. Note that for 2SWF-7 and other cable with polyethylene conductor insulation curing temperature is only 220^{O}F and curing time is longer.

5. Shut off heaters and cool mold to approximately 150^{O}F using wet rags or by allowing to cool at room temperature, then remove cable-plug assembly from mold.

6. When cool enough to handle remove pin adapter with spanner wrench with adapter secured in vise.

7. Trim excess rubber from plug using manicure scissors.

Figure 10-16 shows a neoprene molded MIL-C-24231 plug assembly.

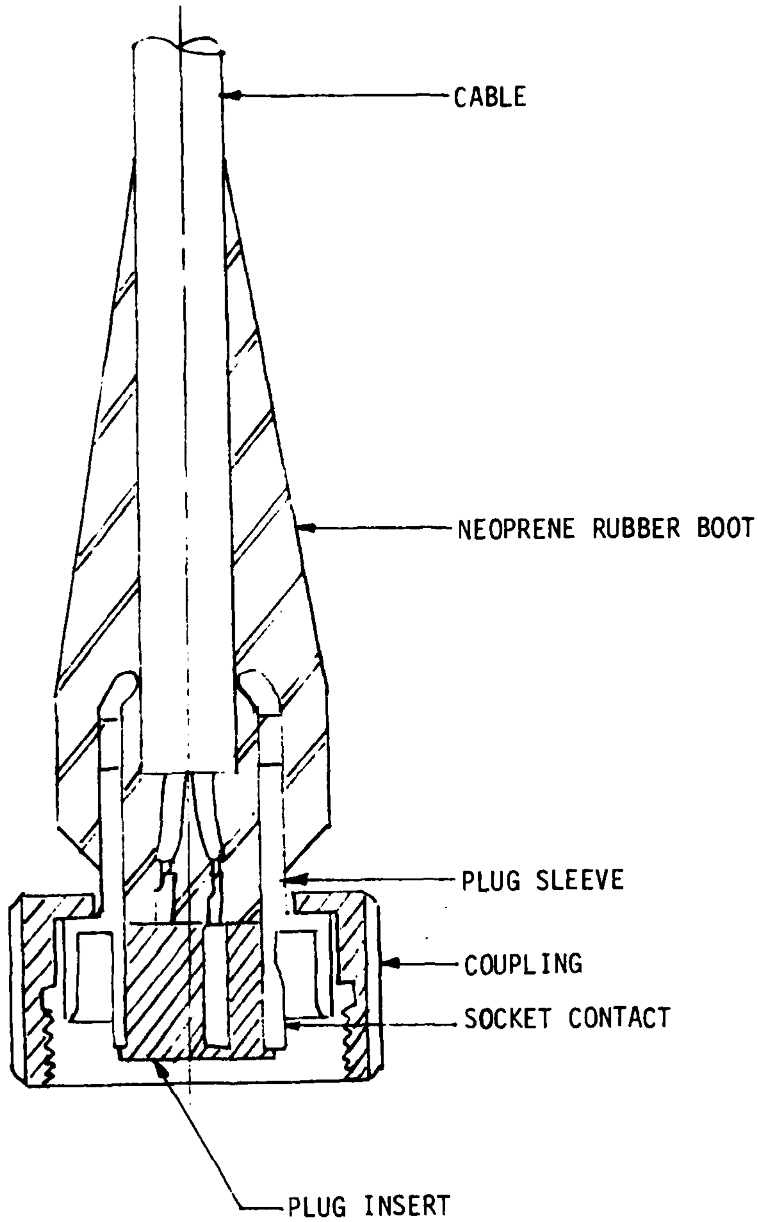


FIGURE 10-16 NEOPRENE MOLDED MIL-C-24231 PLUG ASSEMBLY

10.10 Butyl Rubber Molding AN/BQR-21 Cable Head Assembly

The Naval Weapons Support Center (NWSC), Crane, Indiana, has developed "in house" Navy approved procedures for wiring and butyl rubber molding a cable head assembly for the AN/BQR-21 hydrophones. The cable head assembly consists of a butyl jacketed DSS-3 type cable (without overall shield) with a MIL-C-24231 plug assembly wired and butyl molded to one end (hull penetrator) and a butyl molded cable flange (gland) wired to the hydrophone end. See Figure 10-17 and Reference 10-8. The following wiring and molding procedures are taken from the Reference 10-9 document.

10.10.1 Sandblasting

10.10.1.1 Sandblast the hermetically-sealed, two-terminal feed through for the cable flange.

1. Mask to protect the glass insulation about the terminals. (Hook terminal side).
2. Sandblast only the side presenting the hook formed terminals.
3. Clean the terminals by immersing and agitating them in trichloroethane.

CAUTION

TRICHLOROETHANE IS A POTENTIAL HEALTH HAZARD. USE AN ENERGIZED FUME HOOD FOR THIS CLEANING OPERATION. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. AVOID PROLONGED OR REPEATED BREATHING OF VAPOR. DO NOT PERMIT TRICHLOROETHANE TO CONTACT HEAT OR FLAME. CONTAINERS SHOULD REMAIN CLOSED EXCEPT WHEN IN USE. DO NOT TAKE INTERNALLY. WEAR EYE PROTECTION WHEN USING TRICHLOROETHANE FOR CLEANING PURPOSES.

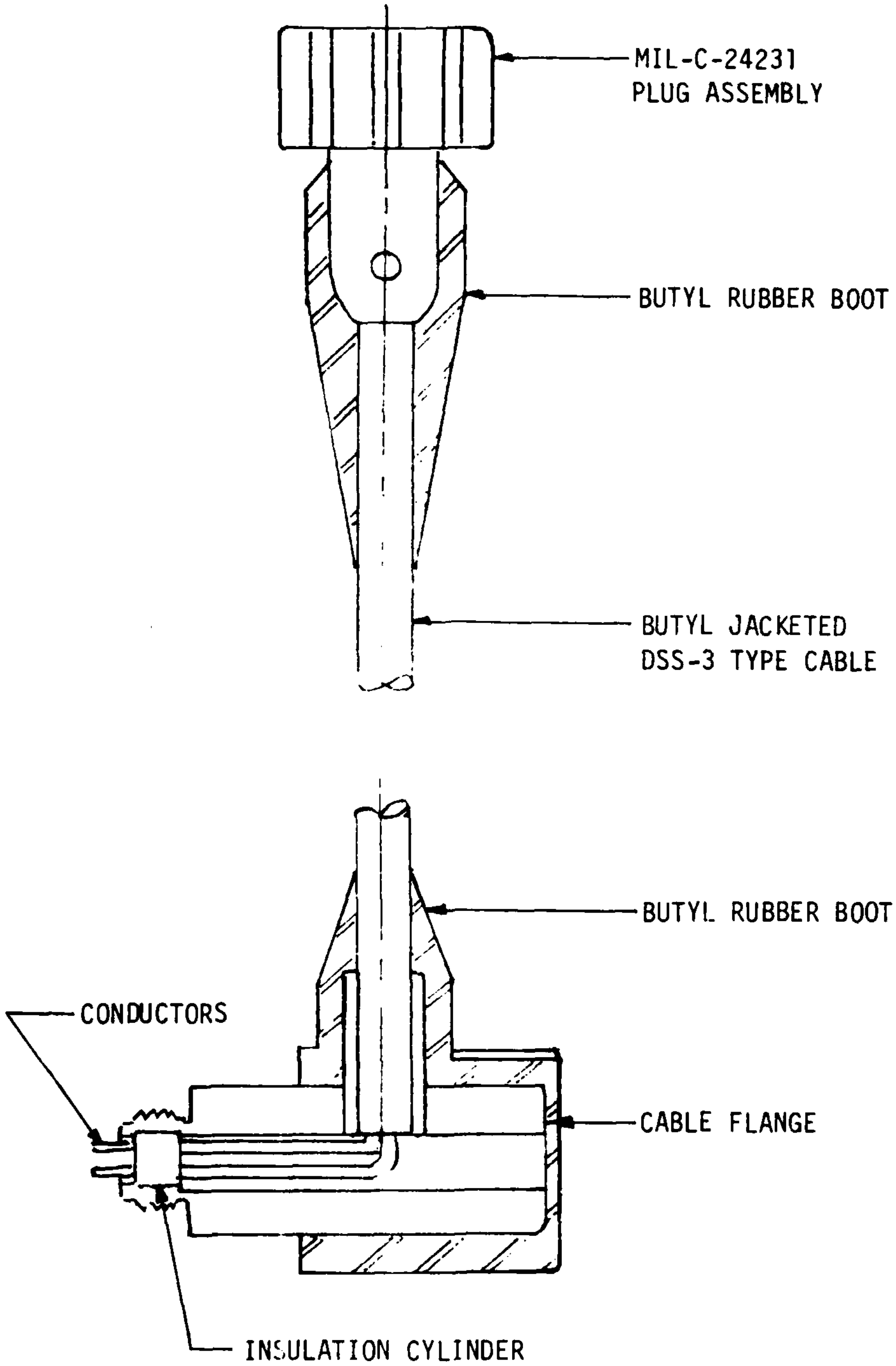


FIGURE 10-17 MWSC AN/BQR-21 CABLE HEAD ASSEMBLY

10.10.1.2 Sandblast MIL-C-24231 Connector Shell

1. To mask flange of the connector shell; install 1-5/16" x 1/4" "O"-ring in cavity; place sandblasted connector nut over the shell; install two 1" x 1/8" "O"-rings over the shell to lock the connector nut in position; insert the threaded plug cap (with 1/2" hole) in the connector nut. See Figure 10-18A illustrates area to be sandblasted).
2. Sandblast the connector shell.
3. Remove hardware from the sandblasted shells.
4. Clean the connector shells by immersing and agitating them in trichloroethane.

NOTE

EXERCISE CARE WHEN HANDLING THE CLEANED COMPONENTS, AVOID CONTAMINATING THE SANDBLASTED AREA.

10.10.1.3 Sandblast Cable Flange

1. Wrap the exposed threads of the cable flange with green cloth tape.
2. Sandblast the assembly.
3. Remove the tape from the threads.
4. Clean the assembly in trichloroethane.

Tools	Expendable Supplies
Direct Pressure Dry Honer (As VacuBlast 200P)	Green Cloth Tape
Fume Hood (Positive Exhaust)	Trichloroethane
	Aluminum Oxide, Grit No. 80, alternate grit is steel.

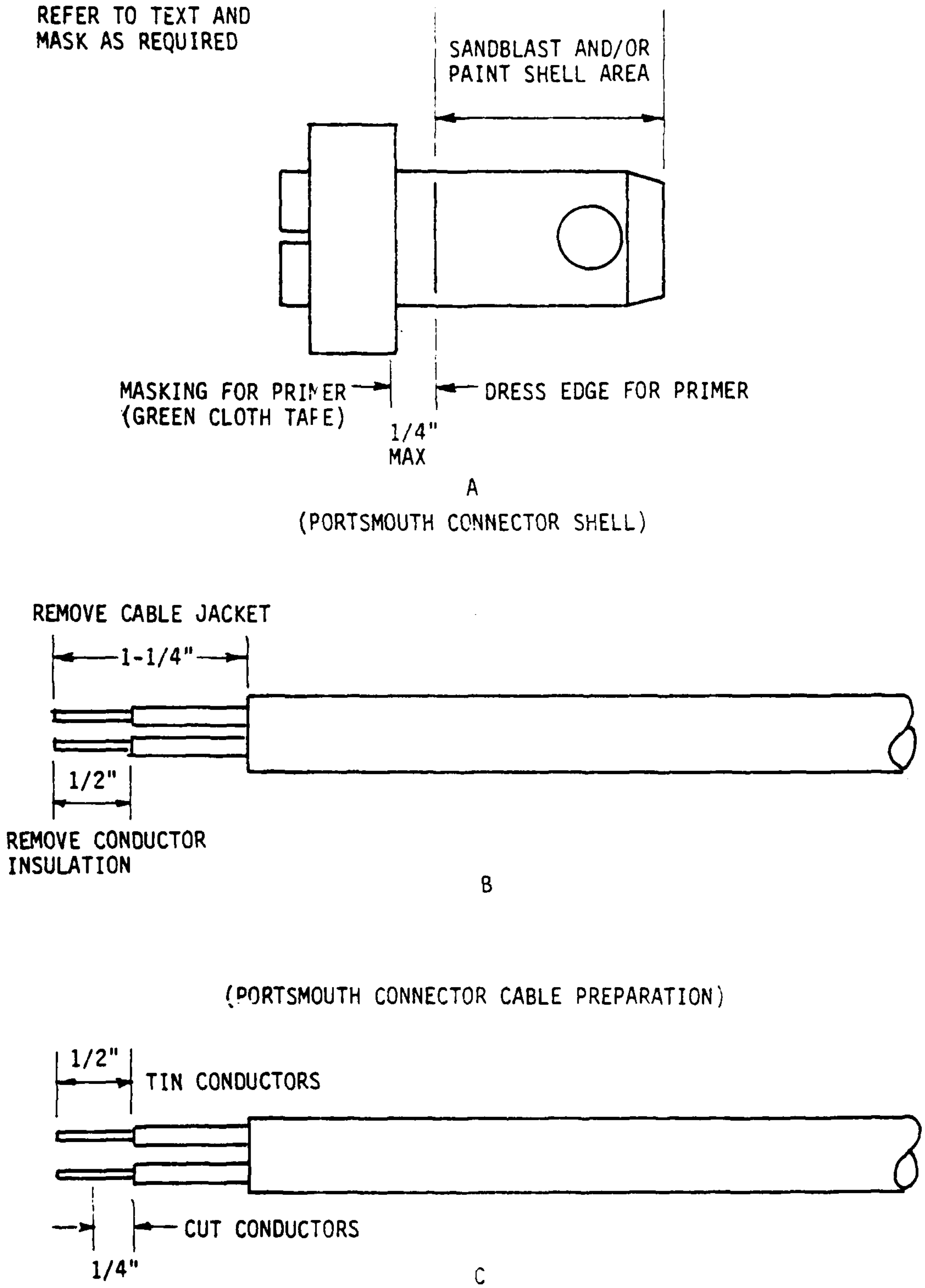


FIGURE 10-18 MIL-C-24231 Plug-Cable Preparation

10.10.2 Preparation of the MIL-C-24231 Plug and Cable

1. Remove approximately 1-1/4 inch of the outer jacket from one end of the cable (see Figure 10-18B).

CAUTION

EXERCISE CARE; DO NOT CUT THE CONDUCTORS OR THEIR INSULATION.

2. Remove the exposed inner jacket (approximately 1-1/4 inch).
3. Remove 1/2 inch insulation from the conductors (see Figure 1B).
4. Dip stripped conductors into the ultrasonic cleaner (trichloroethane) for no less than 1/2 minute. Use acid brush and trichloroethane to clean the conductors. Twist the conductors to make them lay properly. Dip the conductors into the ultrasonic cleaner until all foreign material is removed. Permit to air dry (5 minutes minimum).
5. Dip cleaned conductors into solder flux.
6. Dip fluxed conductors into molten solder to tin.
7. Cut tinned portion of conductors to 1/4 inch (see Figure 10-18C).
8. Dip tinned conductors into the ultrasonic cleaner (trichloroethane), use acid brush and trichloroethane to clean the conductors, momentarily dip the conductors back into the ultrasonic cleaner.

10.10.2 (Continued)

9. Clean (vigorously) the cable with a lint-free cloth moistened in tap water. Clean approximately 10" of the cable.

Tools	Expendable Supplies
Shears, Cable Cutting	Solder SN60 to QQ-S-571
Wire Stripper or Knife	Flux, MIL-F-14256 T-R
Solder Pot	Lint-Free Cloth
Ruler	Trichloroethane
Pliers, Diagonal Cutting	
Pliers, Long Nose	
Ultrasonic Cleaner	
Cable Reeling Equipment	

10. Pretin solder cups of plug insert.

11. Clean the plug inserts by immersing and agitating them in isopropyl alcohol. Permit to air dry, 5 minutes minimum.

WARNING

ISOPROPYL ALCOHOL IS FLAMMABLE. KEEP AWAY FROM HEAT, SPARKS AND OPEN FLAME. MAINTAIN CONTAINERS CLOSED WHEN NOT IN USE. USE WITH ADEQUATE VENTILATION.

12. Load cup with molten solder.

13. Slush out molten solder.

14. Place the plug coupling nut and then the plug shell on the cable.

15. Fit the black conductor into #1 socket contact solder cup; solder in place.

10.10.2 (Continued)

16. Fit the white conductor into #2 socket contact solder cup; solder in place.

17. Visually inspect the soldered connectors to determine that the black wire is in fact soldered to pin #1, the white wire to pin #2, and that the solder connections were properly formed.

18. Use trichloroethane and a stiff brush to clean soldered connections.

19. Apply Resiweld 7004 adhesive to plug shell (area that will receive insert), align insert tab with keyway and install alignment tool (dummy connector). Use FAMCO hand press to seat insert.

NOTE

CHECK SHELF-LIFE EXPIRATION DATE OF RESIWELD 7004 ADHESIVE.

20. Remove alignment tool from plug and check plug and insert for proper seal and seat.

NOTE

OVEN CURE MAY BE PERFORMED IN CONJUNCTION WITH CABLE FLANGE BOOT CURE.

21. Place in oven ($200^{o} \pm 10^{o}F$) for two hours minimum. Record curing start and stop times.

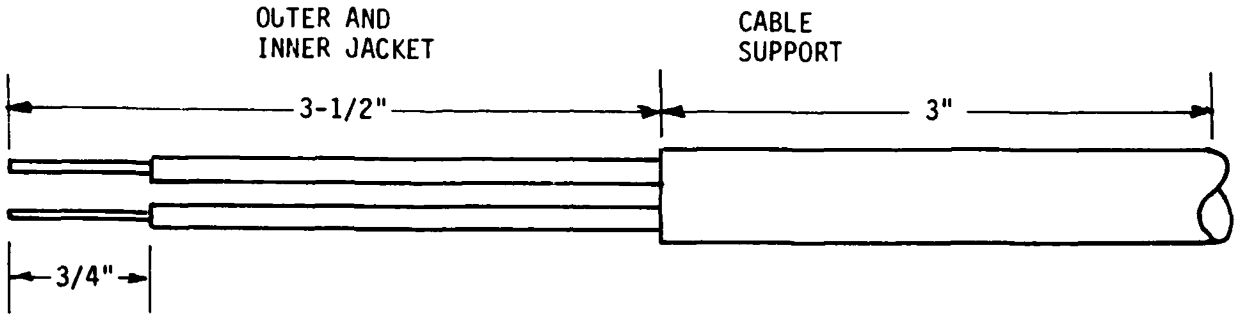
22. After 2 hours, remove from oven and allow to cool to room temperature (approximately one hour).

10.10.2 (Continued)

Tools	Expendable Supplies
Soldering Iron	Trichloroethane
Acid Brush	Resiweld 7004
Hand Press (as FAMCO)	Solder SN60WRP2 to
Dummy Connector (Alignment Tool)	QQ-S-571
	Isopropyl Alcohol

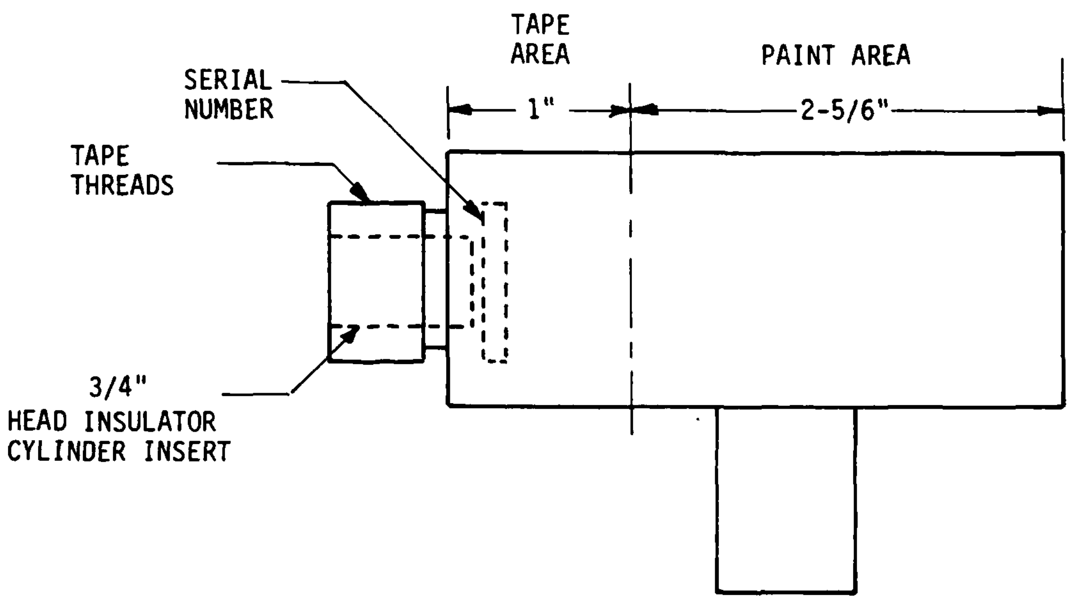
10.10.3 Preparation of the Cable Flange and Cable

1. Remove approximately 3-1/2" of the outer jacket from the end of the cable (see Figure 10-19A).
2. Remove approximately 3-1/2" of the inner jacket from the cable - EXERCISE CARE, do not damage insulation of the individual conductors.
3. Remove approximately 3/4" of the insulation from the ends of the exposed conductors, refer to Figure 10-19A for details.
4. Clean stripped conductors in ultrasonic cleaning tank with trichloroethane, permit to air dry.
5. Mometarily dip the conductors into flux.
6. Insert the fluxed leads into molten solder to tin them.
7. Check leads for proper tinning, dip tinned conductors into the ultrasonic cleaner (trichloreothane), use acid brush and trichloreothane to clean the conductors, momentarily dip the conductors back into the ultra-sonic cleaner.



A

CABLE FLANGE CABLE END



B

CABLE FLANGE

FIGURE 10-19 CABLE FLANGE-CABLE PREPARATION

10.10.3 (Continued)

8. Clean (vigorously) the cable with a lint-free cloth moistened in tap water. Clean approximately 10" of the cable.

Tools	Expendable Supplies
Electric Solder Pot	Solder SN 60 to QQ-S-571
Diagonal Cutting Pliers	Flux, MIL-F-14256, Ty-R
Ruler	Lint-Free Cloth
Wire Strapping Machine	Trichloroethane
Long Nose (Wire Forming) Pliers	
Ultrasonic Cleaner	
Acid Brush	
Knife	

9. Clean phenolic insulating cylinders for this operation by immersing them in trichloroethane and agitating them, permit to air dry for approximately 5 minutes.

10. Apply a thin film of Resiweld 7004 adhesive to the inside surface of the cable flange and insert the phenolic insulating cylinder into the cable flange. (See Figure 10-19B).

NOTE

CHECK SHELF-LIFE EXPIRATION DATE OF RESIWELD 7004 ADHESIVE.

OVEN CURE (STEP 10) MAY BE PERFORMED IN CONJUNCTION WITH PLUG BOOT CURE.

10.10.3 (Continued)

11. Place (threaded end down) on flat surface in oven preheated to 200 $\pm$ 10^{o}F to cure, 2 hours minimum. Log epoxy cure start and stop times.

12. Remove from chamber, permit to cool at room ambient temperature.

13. Hand stamp, 4-digit serial number on cable flange (see Figure 10-19B) and make listing in serial number log book.

14. Form tinned portion of conductors approximately 30^{o}, insert them into the cable support to exit through the phenolic insulating insert.

15. Pull conductors through cable head as the cable proper is stuffed into the cable support tube.

16. Position cable head insulation spacer between the black and white wires, position to extend approximately 1/2" from flange.

17. Solder the black wire to the sandblasted double-feed-through terminal marked B; the white wire to the terminal marked W.

18. After soldering - visually check to determine that the black wire is in fact connected to terminal B and the white to terminal W.

19. Use trichloroethane and a stiff brush to clean connections.

20. Apply a small bead of EPON VI to cable head flange surface that will seat against the feed-through terminal.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF EPON VI ADHESIVE.

10.10.3 (Continued)

21. Pull cable back into head to seat double terminal feed through. Position holding nut over double feed through are tighten to seat (insure double feed through terminals are centered in holding nut).

22. Place cable flange termination through slot of Jensen 3609 temperature chamber, pre-heat to 200 $\pm$ 10^{o}F.

23. Secure power to oven, inject Resiweld 7004 adhesive (in syringe) into cable flange cable exit tube, determine that the cable is forced into the cable exit tube to relieve strain on the conductors at the ends of the conductors.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF RESIWELD 7004 ADHESIVE.

24. Re-energize oven, cure for 2 hours minimum at 200 $\pm$ 10^{o}F. Log oven cure start and stop times.

25. After 2 hour cure, remove assembly from the oven and permit it to cool to room temperature (2 hours minimum).

Tools	Expendable Supplies
Metal Stamp Set	EPON VI adhesive, MMM-A-134
Ball Peen Hammer	Ty-II
Diagonal Cutting Pliers	7004 Adhesive
Needle Nose Pliers	Trichloroethane
Soldering Iron	Solder SN60WRP2 to QQ-S-571
Acid Brush	

10.10.4 Electrical Tests

NOTE

TEST EQUIPMENT MUST BE "IN-CAL", CHECK FOR CALIBRATION DATES.

10.10.4.1 *Insulation Resistance Test*

1. Set test voltage for 1,000 V (unknown terminals).
2. Attach test leads from test equipment to cable flange and/or terminals and test as follows:
   - Black to Cable Flange
   - Black to Connector Shell
   - Black to White
   - White to Connector Shell
   - White to Cable Flange
3. Reject units that test less than 500 megs on any of the tests.

Tools	Expendable Supplies
General Radio Resistance Test Set Model 1644 or 1864	None
Tests Leads as Required	

10.10.4.2 *Continuity Tests*

1. Select R X 1 scale of multimeter.
2. Attach test leads to cable assembly to test:
   - Plug Connector Pin #1 to Cable Flange Pin "B"
   - Plug Connector Pin #2 to Cable Flange Pin "W"
3. Reject units that test more than 0.5 ohms on the continuity test.

10.10.4.2 (Continued)

Tools	Expendable Supplies
Simpson 260 or equivalent Test Leads as required	None

4. Post Test - reinstall terminal holding nut as required.

10.10.5 Prepotting Cable Terminations

1. Wrap 3/4 inch wide green cloth tape one time around plug shell covering holes.
2. Preheat cable flange (insert through lots of Jensen 3609 chamber) and plug connector in oven ($200 \pm 10^{\circ}F$) for 15 minutes.
3. After 15 minutes, secure oven power and fill cable flange and plug connector cavities with Hysol, level with top.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF HYSOL POTTING COMPOUND.

4. Re-energize oven and cure terminations for 2 hours minimum at $200 \pm 10^{\circ}F$, log cure start and stop times.
5. After 2 hours, remove assembly from oven and permit it to cool at ambient room temperature for 2 hours minimum.
6. Chase threads with 7/8" x 14 die to determine that adhesive or feed-through terminal does not interfere with threads. Install thread protector nut.

10.10.6 Termination Preparation for Molding

1. Remove tape from plug connector, remove epoxy residues or splashes from metal parts - use methyl ethyl ketone (MEK).

CAUTION

METHYL ETHYL KETONE IS A POTENTIAL HEALTH HAZARD. USE AN ENERGIZED FUME HOOD FOR THIS CLEANING OPERATION. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. AVOID PROLONGED OR REPEATED BREATHING OF VAPOR. DO NOT PERMIT METHYL ETHYL KETONE TO CONTACT HEAT OR FLAME. CONTAINERS SHOULD REMAIN CLOSED EXCEPT WHEN IN USE. DO NOT TAKE INTERNALLY. WEAR EYE PROTECTION WHEN USING METHYL ETHYL KETONE FOR CLEANING.

2. Wrap the plug connector shell (see Figure 10-18A) with a narrow (1/4" or less) strip of green cloth tape to establish a dress edge for the primers at the very edge of the sandblasted area. Mask the mating end of the connector with masking tape.
3. Remove epoxy residues or splashes from cable flange (metal parts - use methyl ethyl ketone).
4. Wrap cable flange body (see Figure 10-19B) one inch (from threaded end) with green cloth tape.
5. In energized fume hood, apply a coat of Chemlok 205 metal-to-rubber adhesive primer to the exposed surface of MIL-C-24231 connector shell and allow to air dry (drying time shall be 20 minutes minimum).

10.10.6 (Continued)

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF CHEMLOK 205; STIR PRIOR TO USE.

CAUTION

EXERCISE GREAT CARE TO AVOID TOUCHING OR OTHERWISE CONTAMINATING THE PRIMED (OR OTHERWISE COATED) PARTS AND/OR CABLE.

6. After the first coat is dry; apply a second coat of Chemlok 205 and allow to air dry (20 minutes minimum).

7. After the second coat is dry, apply a coat of Chemlok 236 adhesive over the Chemlok 205 and allow to air dry (30 minutes minimum).

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF CHEMLOK 236; STIR PRIOR TO USE.

8. Apply a second coat of Chemlok 236 (after the first coat has dried) and allow to air dry, 30 minutes minimum.

9. After second coat of Chemlok 236 is dry, remove green tape from shell, slide connector nut down over connector shell and install threaded dust cap.

10. Abrade approximately 6" of cable with stiff wire brush (hand tool - do not use power), clean abraded cable and MIL-C-24231 connector with dry, clean, oil free air.

10.10.6 (Continued)

CAUTION

AIR PRESSURE OF AIR USED FOR CLEANING MUST BE REDUCED TO 30 PSI OR LESS. NEVER DIRECT COMPRESSED AIR AT ANY PART OF THE BODY OR AT ANOTHER PERSON. WEAR EYE PROTECTION WHEN USING COMPRESSED AIR.

11. Wrap cleaned-abraded cable with prepared tie-stock (see paragraph 10.10.11 for tie stock mixing), stretch on application to reduce thickness to approximately 0.02", continue up cable to extend approximately 3" from the MIL-C-24231 connector.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF TIE STOCK.

12. Wrap the primed area of the plug connector and the portion of the cable that is covered with tie-stock, a total wrap of approximately 4 inches overall, with butyl strips. Wrap to conform to the overall general appearance of the finished strain relief, use 3 strips of butyl 27" long, fold an 8" piece of butyl and place it on that side of the product that the identification is to be molded. Use a 27" strip of butyl to form a butyl slug, roll strip tightly into a cylindrical shape.

NOTE

BUTYL RUBBER IS A SHELF LIFE ITEM, CHECK EXPIRATION DATE.

10.10.6 (Continued)

13. In energized fume hood, apply a coat of Chemlok 205 metal-to-rubber primer to the exposed metal surfaces of the cable flange body. Allow to air dry for 20 minutes minimum.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF CHEMLOK 205; STIR PRIOR TO USE.

14. After the first coat is dry, apply a second coat of Chemlok 205 over the first coat and allow to air dry (20 minutes minimum).

15. After the second coat is dry, apply a coat of Chemlok 236 over the second coat of 205 and allow to air dry (30 minutes minimum).

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF CHEMLOK 236; STIR PRIOR TO USE.

16. After the first coat of Chemlok 236 is dry, apply a second coat and permit to air dry for 30 minutes minimum.

17. After the second coat of Chemlok 236 is dry, remove the green tape from the cable flange.

18. Abrade approximately 4-1/2 inches of cable with stif-wire brush (hand tool - do not use power), clean abraded cable and cable flange with dry air.

10.10.6 (Continued)

19. Wrap cleaned-abraded cable with prepared tie-stock, stretch on application to reduce thickness to approximately 0.02", continue up the cable to extend approximately 1-1/2 inches from the cable flange.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF TIE-STOCK.

20. Use two 10" and four 31-1/2" strips of butyl to wrap the cable flange and the first inch of the cable - to the approximate form of the mold cavity. Cut and place three 3" and six 2" pieces of butyl on that side of the product that the identification is to be molded.

NOTE

BUTYL RUBBER IS A SHELF LIFE ITEM, CHECK EXPIRATION DATE.

21. Use three 31-1/2" strips of butyl to form a cylindrical slug.

22. Measure diameter of cable. Select proper cable mold clamps and loosely install them at both terminations. Install them in their approximate positions for molding.

23. Remove thread protection nut and install terminal holding nut for molding.

Tools	Expendable Supplies
Allen Wrench 9/64"	Masking Tape
Brushes	Green Cloth Tape
Shears or Knife	Butyl

10.10.6 (Continued)

Tools	Expendable Supplies
Wire Brush (hand tool)	Chemlok 205
Mold Clamps	Chemlok 236
Terminal Holding Nut	Tie Stock (Procedure 305)
	Epoxy, Hysol
	Methyl Ethyl Ketone

10.10.7 Molding the Cable Terminations - Either end may be molded first or if presses are available, both ends may be molded concurrently.

1. Preheat molds on preheated press (320 $\pm$ 10°F) for 45 minutes. Use press timer to measure preheat interval.

NOTE

PRESS(ES) USED FOR MOLDING MUST BE "IN-CAL", CHECK FOR CALIBRATION DATES PRIOR TO INITIATING PREHEAT.

2. Prior to being used for the first time each day, the mold temperature must be monitored and the press temperature adjusted as required. After press and mold have preheated and equipment is stable, insert temperature monitoring probe into probe cavity of mold (first use, each day).

   (a) Read temperature, 320°F.
   (b) If not very close to 320° ($\pm$ 5°F), adjust temperature control.
   (c) Allow temperature to stabilize.
   (d) Read temperature.

10.10.7 (Continued)

(e) Repeat Steps (a) through (d) until mold is stable at 320°F ($\pm$ 5°F).

CAUTION

WEAR HEAT RESISTANT GLOVES WHEN HANDLING HEATED MOLDS.

3. Place the prepared plug connector into the preheated mold.

(a) Position cable clamp to allow assembly to fit into mold, tighten screws of cable clamp.

(b) Position the connector nut tightly against end of mold.

Inspect to determine that the prepared portion of the metal sleeve extends from the cavity to provide complete butyl-to-metal bonding within the mold cavity.

(c) Position the remaining mold piece over the guide pins.

(d) Tighten the jack screw against the connector nut protective cap to seat the assembly in the mold.

(e) Tighten the four holding screws to assemble the mold.

(f) Place the butyl slug previously formed in the transfer cavity.

(g) Install the transfer piston (with piston removal hole out) in the transfer cavity over the butyl slug.

10.10.7 (Continued)

4. Place the assembly in the preheated press (stable at $320^{\circ} \pm 10^{\circ}F$) and slowly adjust the press to close the mold.

5. Gradually increase press pressure to 25,000 $\pm$ 5,000 pounds.

6. Set interval timer for 60 minutes.

7. After time interval expires (wear asbestos gloves), remove assembly from press.

8. Carefully remove the assembly from the mold.

9. Clean mold, use wood probe and compressed air to remove all vulcanized rubber from mold cavities, injection holes and from extrusion holes.

NOTE

RETURN MOLD PIECES TO HEATED PRESS FOR CONTINUED OPERATIONS.

10. Permit molded strain relief to cool to room ambient temperature, one hour minimum.

NOTE

DO NOT STRESS OR TEST (TO INCLUDE THE NON-DESTRUCTIVE BONDING TEST OF MIL-C-24231) UNTIL 24 HOURS AFTER REMOVAL FROM THE MOLD.

10.10.7 (Continued)

11. After the assembly has cooled (1 hour minimum), remove cable clamp and trim the flashing and other excess material from the molded strain relief of the plug connector, trim to 0.015" maximum.

CAUTION

ALWAYS WEAR HEAT RESISTANT GLOVES WHEN HANDLING HEATED MOLD OR MATERIALS AT THE PRESSES.

NOTE

CABLE FLANGE MOLD WILL BE "TEMPERATURE MONITORED AND ADJUSTED" TO THE PROPER TEMPERATURE PRIOR TO BEING USED FOR THE FIRST TIME EACH DAY THAT IT IS USED.

12. Remove preheated cable flange mold from press.

13. Place prepared cable flange in mold.

    (a) Position cable clamp to allow assembly to fit into mold, tighten screws of cable clamps.

14. Position the remaining mold section (guide pins), tighten the 4 screws to assemble the mold.

15. Place the butyl slug previously formed in the transfer cavity.

16. Install the transfer piston (hole out) in the transfer cavity, over the butyl slug.

10.10.7 (Continued)

17. Place the assembly on the preheated press (stable at 320 $\pm$ 10^{o}F) and slowly adjust the press to contact mold.

18. Use air pump to close press to bring transfer piston into the mold (pressure shows on gauges). Use jacking handle to increase pressure.

19. Jack up press pressure to 30,000 $\pm$ 5,000 pounds.

20. Set timer for one hour.

21. After time interval expires; release press pressure and remove mold.

CAUTION

WEAR HEAT RESISTANT GLOVES WHEN HANDLING HEATED MOLDS.

NOTE

RETURN MOLD PIECES TO HEATED PRESS FOR CONTINUED OPERATIONS.

22. Carefully remove cable flange from mold and permit it to cool to room ambient temperature (1 hour minimum).

NOTE

DO NOT STRESS OR TEST UNTIL 24 HOURS AFTER REMOVAL FROM MOLD.

23. Clean mold, use wood probe and compressed air to remove all vulcanized rubber from mold cavities, injection holes from the extrusion holes.

10.10.7 (Continued)

24. After the assembly has cooled (1 hour minimum), remove cable clamp and trim the flashing and other excess material from the molded cable flange and strain relief. Remove terminal holding nut and install thread protecting nut. Trim to 0.015" maximum.

25. After the plug connector has cooled at least 24 hours, perform the non-destructive bonding test of MIL-C-24231 (Figure 1) at no less than four points. Do not pry against coupling nut. Place probe on molded rubber 1/4 inch from termination and lift. Do not tear butyl rubber. Any indication of separation will dictate rejection.

26. Carefully inspect the strain relief-to-cable bonds (both terminations). Any indication of separation will dictate rejection.

27. Use electric hot stamp to impress inspection lot number (month and year) on the molded strain relief of the Portsmouth connector, side opposite molded part number.

Tools	Expendable Supplies
Thread Protecting Nut	None
Asbestos Gloves	
Interval Timer	
Shears or Knife	
Electric Hot Stamp (as Everhot Ty-82)	
Allen Wrench Set	
Probe (per MIL-C-24231 Figure 1)	

10.10.8 Acceptance Electrical Tests

NOTE

TEST EQUIPMENT MUST BE "IN-CAL", CHECK FOR CALIBRATION DATES.

10.10.8.1 *Insulation Resistance Test*

1. Set test voltage (unknown terminals) for 1000 V.
2. Attach leads from test equipment to cable flange and/or terminals and test as follows:
   - Black to Cable FLange
   - Black to Connector
   - Black to White
   - White to Connector
   - White to Cable Flange
3. Reject units that test less than 500 megs on the insulation tests.

Tools	Expendable Supplies
Resistance Test Set, General Radio 1644 or 1864 Test Leads as required	None

10.10.8.2 *Continuity Test*

1. Select R X 1 scale of multimeter.
2. Attach test leads to cable assembly to test:

   - Connector Pin #1 to Cable Flange Pin "B"
   - Connector Pin #2 to Cable Flange Pin "W"

3. Reject units that test more than 0.5 ohms on the continuity test.

Tools	Expendable Supplies
Simpson 260 or equivalent	None
Test Leads as required	

4. Post test, re-install plug cap and cable flange protective nut.

10.10.9 Acceptance Cable Length Check

1. Lay out cable to measure against calibrated markers for length check.
2. Accept all cables measuring 73 to 77 feet.
3. Reject all non-conforming material.

10.10.10 Acceptance Visual Inspection Check

1. Inspect cable.
2. Threads (with 7/8" x 14 die), turn die onto threads to determine that feed-through or glue does not interfere with threads.
3. Feed-through (and mounting) should be flush and centered.
4. Cable flange, general, exhibit no voids of depth in excess of 0.03", flashing should be trimmed neatly, 0.015 maximum.
5. Cable flange strain relief-to-cable bond, bend cable in an arc to determine that the strain relief has not separated from the cable.
6. Plug connector, inspection lot number, impressed on side opposite molded part number.
7. Plug connector, strain relief-to-cable bond, bend cable in an arc to determine that the strain relief has not separated from the cable.

Tools	Expendable Supplies
Die 7/8 - 14	None

10.10.11 Preparation of Tie Stock (For Bonding Unvulcanized Butyl to Vulcanized Butyl Cable Jacket)

1. Remove paper back from a roll of butyl tape or measure out (from bulk) to accumulate 25 grams of material on scale. Fold tape as you work to maintain cleanliness and control of material.

10.10.11 (Continued)

CAUTION

SCALES USED MUST BE "IN-CAL", CHECK CALIBRATION DUE DATE.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF BUTYL RUBBER.

2. Weigh out 25 grams of tac-i-fier.

NOTE

CHECK SHELF LIFE EXPIRATION DATE OF TAC-I-FIER.

3. Masticate butyl and tac-i-fier for 5 minutes (minimum).

4. When tie stock is blended, roll the material to approximately 0.03" thickness and strip it from the mill.

5. Cut the tie stock into strips of approximately 0.75" width.

6. Place strips on plastic wrap, separate layers of prepared tie stock with a sheet of plastic. Cover with a sheet of plastic.

7. Place a piece of masking tape with shelf life expiration date on the package of tie stock.

NOTE

SHELF LIFE OF PREPARED TIE STOCK IS 12 MONTHS WHEN STORED AT 40°F OR LESS.

10.10.11 (Continued)

8. Place material in refrigerator (40^{o}F or less).

Tools	Expendable Supplies
Accurate scales, 25 grams (In-Cal)	Plastic Wrap
	Masking Tape
Rubber Mill	Butyl Tape
Shears, Paper Cutting	Tac-i-fier

10.10.12 Butyl Vulcanizer Rubber Formulation

The following establishes the requirements for the procurement of a Black Butyl Jacket Vulcanizer Rubber designed for use with butyl cable.

1. Requirements (Uncured)

(a) Construction: The rubber shall be a special chlorobutyl compound NASL H862A; Composition Concentration PPH of Rubber:

1.	Chlorobutyl HT-1066	100
2.	Stearic Acid	1
3.	Sterling V Black	50
4.	AC Polyethylene 617A	3
5.	Litharge	10
6.	Maglite A	1
7.	DPG	2
8.	NA 22	1.5
9.	Zinc Oxide	5

10.10.12 (Continued)

Suggested Procedure: Masticate Chlorobutyl HT-1066, add mixture of Sterling V Black and AC Polyethylene 617A, mix well, add remainder of ingredients in specified sequence.

(b) Shelf life of the rubber when stored at $40^{o}F$ (maximum) - 2 years.

(c) Rubber may be in bulk form or in tape form, see Note 5.1.

2. Recommended Curing Requirements

(a) Vulcanizing Temperature - $320^{o} \pm 10^{o}F$

(b) Time - 60 minutes nominal (time may vary, depending on mass).

3. Nominal Physical Properties When Cured in Accordance With Paragraph 3

(a) Tensile strength (psi) - 1500 nominal

(b) Hardness Shore A - 55 nominal

4. Notes

(a) The material in the tape form shall be adequately protected to insure that the layers do not stick together.

5. Identification and Marking

(a) Identify container with vendor's part number and date of manufacture per MIL-STD-130.

10.10.12 (Continued)

Suggested Source of Supply - Identification of the "Suggested Source(s) of Supply" hereon is not to be construed as a guarantee of present or continued availability as a source of supply for the item(s).

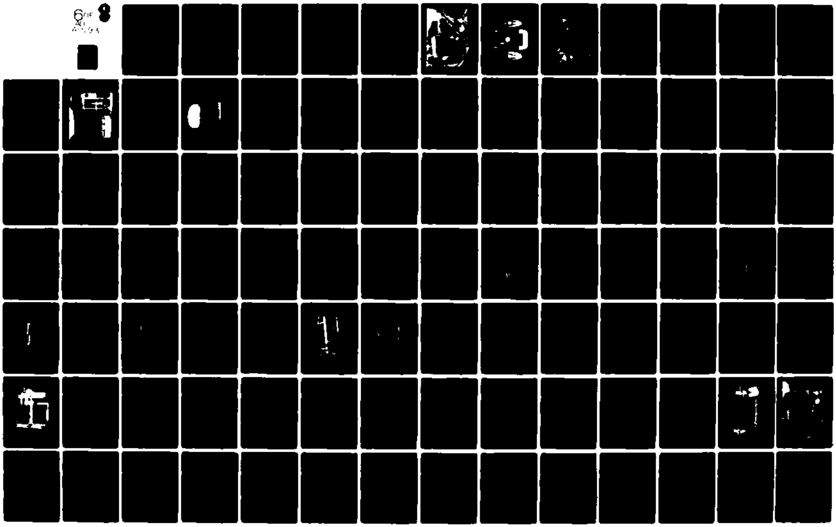
NAVSEA PART NO.	RUBBER FORM	SUGGESTED SOURCE OF SUPPLY	VENDORS PART NO.
4551226-001	Tape Approx. .03 Thick X .75 Wide	Bishop Electric 10 Canfield Road Cedar Grove, NJ 07009 Code Ident. 82053	220-91
4551226-002	Bulk	Garrett Flexible Products 1100 S. Cowan St. Garrett, IN, 46738	1251

NOTE: From Reference 10-10.

AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

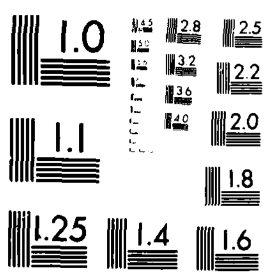
UNCLASSIFIED NRL-MR-4601 NL

6 OF 8



6 OF 8

AD
A111931



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

10.10.13 Butyl Vulcanizer Interface Rubber Formulation

The following establishes the requirements for the procurement of a black interface rubber tac-i-fier designed for use as a part of tie stock for bonding unvulcanized butyl to a vulcanized butyl cable.

1. Requirements (Uncured)

   (a) Composition - A mixture of natural rubbers, carbon black and accelerators.

   (b) Color - Black.

   (c) Durometer, Shore A - 65 $\pm$ 5

   (d) Shelf life @ 25°C $\pm$ 5°C - 3 months
   @ 0°C $\pm$ 5°C - 2 years

   (e) Specific gravity - 1.1

2. Recommended Curing/Use

   (a) Masticate equal parts by weight of tac-i-fier and butyl vulcanizer tape 80064, 4551226 for approximately five minutes in rubber mill.

   (b) Remove well-mixed material from mill in an approximately 0.03 inch thick sheet and wrap prepared cable with this tie stock, overwrap with butyl vulcanizer tape.

   (c) Normal cure - 320°F $\pm$ 10°F for 60 minutes (or as dictated by mass).

   (d) Shelf life of tie stock @ 25°C $\pm$ 5°C - 3 months
   @ 0°C $\pm$ 5°C - 1 year

10.10.13 (Continued)

3. Identification and Marking

   (a) Identify shipping carton with vendor's part number and date of manufacture per MIL-STD-130.

4. Notes

   (a) Packaging.

   (b) Material shall be prepared as bulk sheets not to exceed .250 inch.

   (c) Width and length shall be specified by procuring activity.

   (d) Sheets shall be separated by sheet plastic.

Suggested Source of Supply:

Garrett Flexible Products, Inc.
1100 S. Cowan Street
Garrett, IN 46738

Code Identification Vendor's Part No.: 204

NOTE: From Reference 10-11.

10.11 Bonding Polyethylene to K-Monel Metal

10.11.1 Commercial Capabilities

At least three, pressure-proof, connector manufacturers are known by the Navy to have produced satisfactory proprietary polyethylene to metal bonds for TRIDENT hull penetrator fabrication (Reference 10-21). They are:

ITT Cannon Electric Division
2801 Air Lane
Phoenix, AR 85034

D.G. O'Brien, Inc.,
P.O. Box 159
1 Chase Park
Seabrook, NH 03874

Viking Industries
9324 Topanga Canyon Blvd.
Chatsworth, CA 91311

Also, under the TRIDENT submarine development program, Electric Boat Division conducted basic polyethylene to metal bonding studies which led to a feasible molding procedure (References 10-13 through 10-15).

10.11.2 Electric Boat Division Basic Study Findings

The principal findings of the polyethylene to K-Monel metal basic bonding studies were as follows:

1. Bonds produced by applying polyethylene directly to K-Monel metal or to the metal primed with a variety of adhesives were unsatisfactory.
2. To achieve a good bond of polyethylene to K-Monel metal, an intermediary copolymer precoat, such as an Ionomer or an ethylene-acrylic copolymer, was essential. The ionomers, Surlyn 1650 (DuPont), Surlyn 1652 (DuPont) and the ethylene-acrylic copolymer, PZ 4333·09 (Dow) performed satisfactorily. Good bonds were consistently attained with Surlyn 1650.
3. Bonds prepared with copolymers as precoats, without an adhesive primer on the metal, failed within a few days when immersed and stressed in sea water even though exhibiting polyethylene cohesive failure when tested dry.
4. To achieve a polyethylene/copolymer to metal bond resistant to stress in sea water, the metal must be primed with an adhesive. FM-47 (American Cyanamid), a liquid, vinyl-phenolic adhesive, was investigated intensively and consistently produced water resistant bonds. Some evidence was obtained that FM-73, BR-238, FM-238 and FM-1000 were also satisfactory (all American Cyanamid).

10.11.2 (Continued)

5. Evidence was obtained that the addition of peroxide (Vulcup-R, Hercules) or glass fibers (Owens-Corning) to the copolymers increased peel strength. Since actual strength required is not known, these findings were not pursued.

Findings of Electric Boat Division basic studies (Reference 10-12) were transmitted to the three manufacturers given in Section 10.11.1. However, it is not known if any of these concepts were incorporated into their proprietary molding processes.

10.11.3 Electric Boat Division Molding Equipment and Procedure

Basic studies were continued to develop a molding procedure. Details may be found in Reference 10-15. A variety of polyethylenes, adhesives and copolymers were investigated during procedure development. Use of Surlyn 1650 by itself, in place of polethylene in conjunction with a Surlyn 1650 precoat, produced well bonded transparent connectors. Control of mold temperature was found to be more important than extruder temperature in achieving good bonding when molding connectors.

The apparatus constructed for molding connectors is shown in Figure 10-20. The components identified by numbers in the figure are as follows: (1) air cooling control valve, (2) mold temperature monitor, (3) extruder temperature control, (4) mold ready for injection, and (5) extruder. The molds used for applying a Surlyn 1650 precoat to a FM-47 primed connector shell and for molding the connector plug are shown in Figures 10-21 and 10-22, respectively.

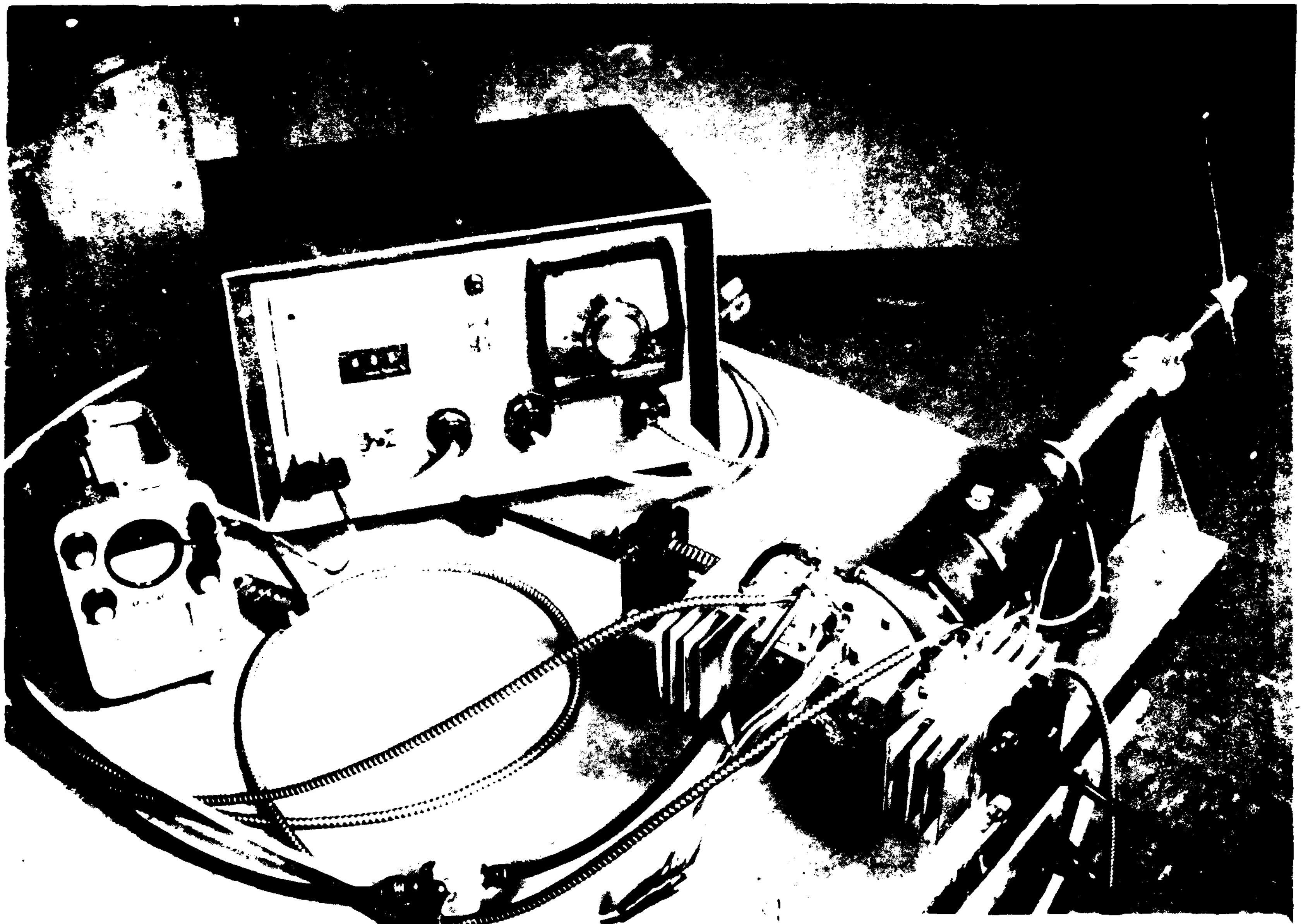
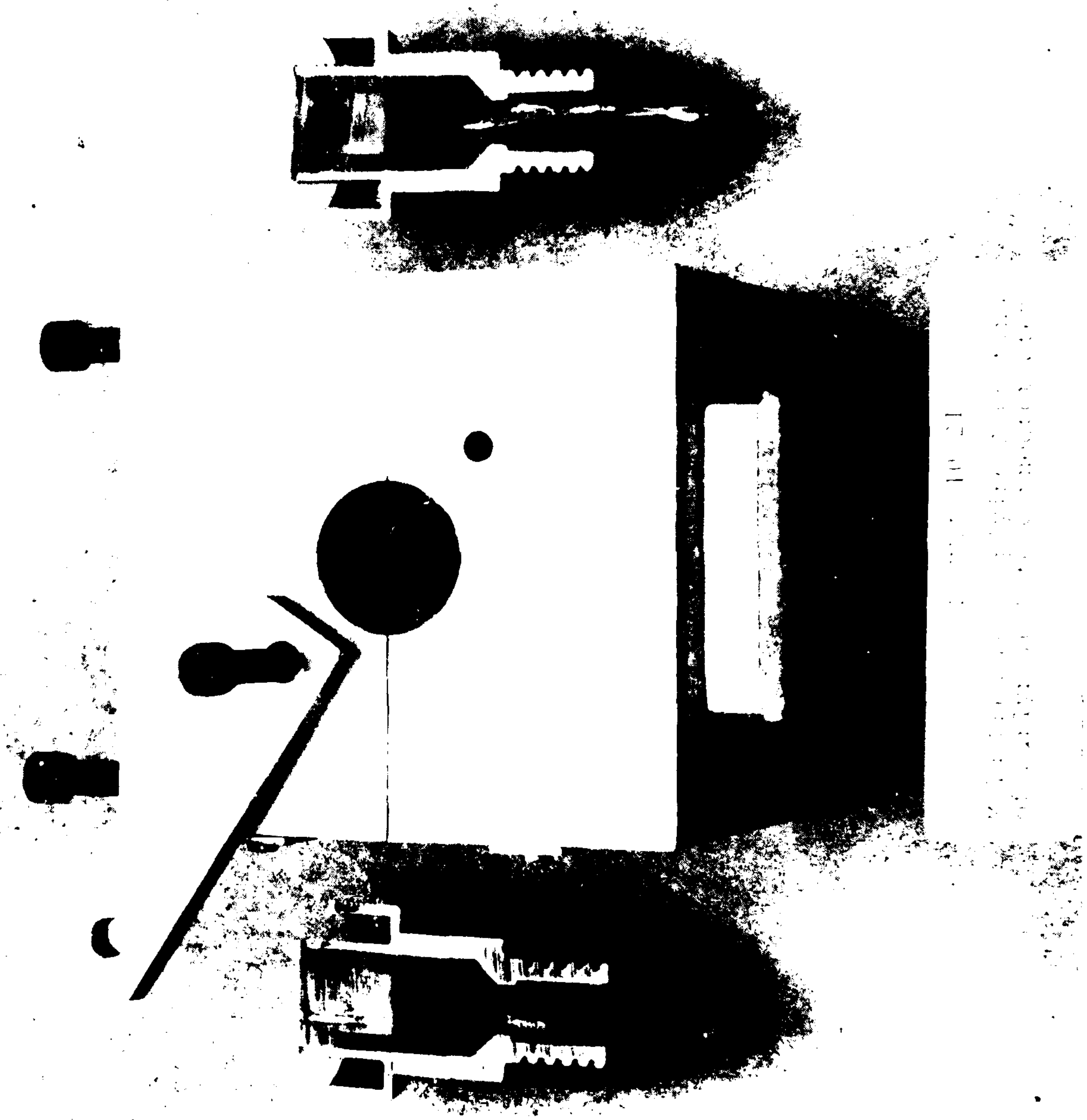
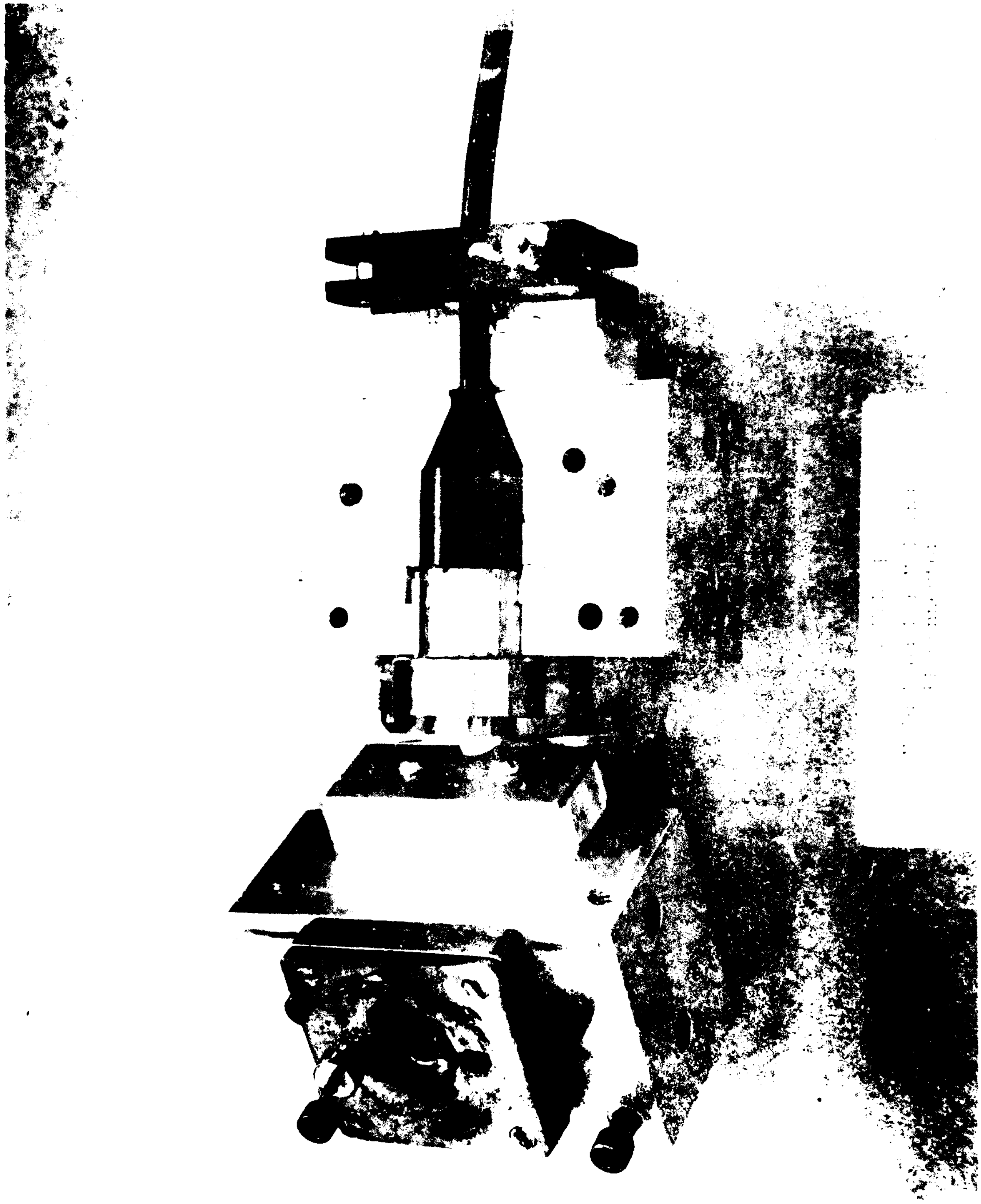


FIGURE 10-20

Mold and Extruder Temperature Control Apparatus





10.11.3 (Continued)

The procedure found to produce well bonded connectors was as follows:

1. Vapor degrease the K-Monel connector shell in trichloroethylene.
2. Apply protective tape on shell areas not to be gritblasted.
3. Gritblast areas to be bonded with 16-20 mesh grit (Black Beauty).
4. Remove tape and clean taped areas.
5. Repeat Step 1.
6. Brush ooat gritblasted areas with FM-47 (American Cyanamid) adhesive diluted to 5% solids with FM-47 American Cyanamid thinner. Air dry 10-15 minutes.
7. Repeat Step 6 brushing in direction opposite to first coating. (Adhesive should be about 5 mils thick).
8. Place connector in Surlyn coating mold and heat mold to 200°F.
9. When mold reaches 200°F, inject Surlyn 1650 at extruder temperature of 450°F to produce a (65 mil) coating.
10. Air cool, with mold attached to extruder. Maintain pressure on Surlyn slug until mold cools to approximately 100°F.
11. Pot IPR-A-20E cable to Surlyn 1650 coated connector.
12. Wipe Surlyn 1650 coated stem polyethylene cable jacket with methyl ethyl ketone in areas to be bonded to remove potential contamination introduced by handling during potting operation.

10.11.3 (Continued)

13. Place coated connector in connector mold and heat mold to $300^{\circ}F$.

14. Inject with polyethylene at extruder temperature of $450^{\circ}F$.

15. Air cool mold with mold attached to extruder. Maintain pressure on polyethylene slug until mold cools to approximately $100^{\circ}F$.

16. Trim flashing.

10.12 Ethylene Propylene Diene Monomer Bonding to AN/BRA-8 Cable Glands

The Naval Underwater Systems Center (NUSC), New London, CT, has a requirements on the AN/BRA-8 towed array to provide a pressure-proof seal to polypropylene insulated conductors, a polyethylene belt (jacket) and a monel metal cable gland. Reference 10-16 provides details of the AN-BRA-8 cable gland seal. The following details and procedures are extracted from this paper.

10.12.1 Compound Development

Research work was conducted by the Springborn Laboratories, Hazardville Station, Enfield, CT, 06082, for NUSC and the Office of Naval Research regarding the bonding of cable insulation materials, References 10-17 and 18.

In this work on Ethylene Propylene Diene Monomer (EPDM) rubber compound was formulated to meet certain properties and/or characteristics in order to perform well as a cable splicing compound. This EPDM rubber proved to be capable of developing chemical bonds to a number of materials, including polypropylene and polyethylene.

The EPDM formulation developed by Springborn Labs and used on the AN/BRQ-8 system has the following composition:

PHR	Ingredient	Trade Designation/Source
100	EPDM	Nordel 1320/E.I. DuPont Company
20	Carbon Black	Vulcan 3/Cabot Corporation
10	Polyethylene	DFD-0166/Union Carbide
5	Zinc Oxide	Kadoz 72/New Jersey Zinc
14.7	Saret 298	75% dry mix in Microsil/Kenrich Petrochemicals
7.7	Catalyst	Luperco 231-XL/Lucidol/Penwalt

10.12.1 (Continued)

The compound needed a certain degree of reactivity to insure that a successful bond was developed with the polypropylene insulation. A terpolymer of EP rubber was selected, because of the double bond which adds to the reactivity of the compound. In splicing and terminating cables, it is necessary to work with the individual conductors which are very flexible in the smaller wire sizes. It is therefore necessary to have a compound with a low viscosity in the uncured state to reduce conductor distortion during the molding process. The Nordel 1320 was selected because of its low viscosity. The cure system uses a peroxide catalyst system. The Luperco 231-XL, a peroxyketal, was selected since it gave satisfactory results over a wide range of cure temperatures. This allows the use of one compound for bonding to polyethylene at 240^{O}F and polypropylene at 310^{O}F. The carbon black is added to attain better physical properties. For a more detailed description of the development and testing of this EPDM formulation, see Reference 10-18.

10.12.2 Termination Procedure

The AN/BRA-8 tow cable has four polypropylene insulated conductors and four ground wires contained in an extruded polyethylene protective belt. Around this core are two layers of galvanized steel armour. In the assembly of this termination two bonds are developed, the primary bond between the polypropylene insulation, the Monel base receptacle, and the EPDM compound and a secondary bond between the polyethylene belt and the EPDM compound. In order to ensure a satisfactory bond, each surface must be prepared and treated prior to the molding process. The surface preparations used are those which proved most satisfactory during the testing conducted at

10.12.2 (Continued)

Springborn Labs. These preparations rely heavily on products manufactured by Dayton Coatings and Chemicals and mar d under the trade name of THIXON.

The surfaces of the polypropylene and the polyethylene are prepared in the following manner. First the outside diameter is lightly abraded with an emery paper. The surface is then washed with trichloroethane and blown dry with a heat gun. Finally a light coat of well mixed THIXON 814 adhesive is applied and allowed to dry for at least 30 minutes prior to molding.

The Monel base cable gland is first grit blasted with No. 70 grit aluminum oxide and then degreased with trichloroethane. Two coats of THIXON P-9 primer and one coat of THIXON 814 are brushed on and allowed to dry for at least 30 minutes between coats. The cable gland is stored in this condition until two hours prior to molding when it is given a final coat of THIXON 814 adhesive.

This is the extent of the surface preparation required for use of this molding technique on polypropylene, polyethylene, and Monel. It cannot be over-emphasized that the care taken in these preliminary steps are essential to the successful development of a watertight molded termination.

The molding apparatus used to terminate the AN/BRA-8 cables is shown in Figure 10-23. It consists of three major components; the assembled mold, the press and the temperature control unit. The mold is a three part assembly into which is fastened an assembled and primed cable end. On top of the mold is mounted the reservoir which contains the EPDM during the initial heat up and the transfer operations. Off the front of the mold is mounted a water cooled collar which protects the cable jacket during the curing cycle.

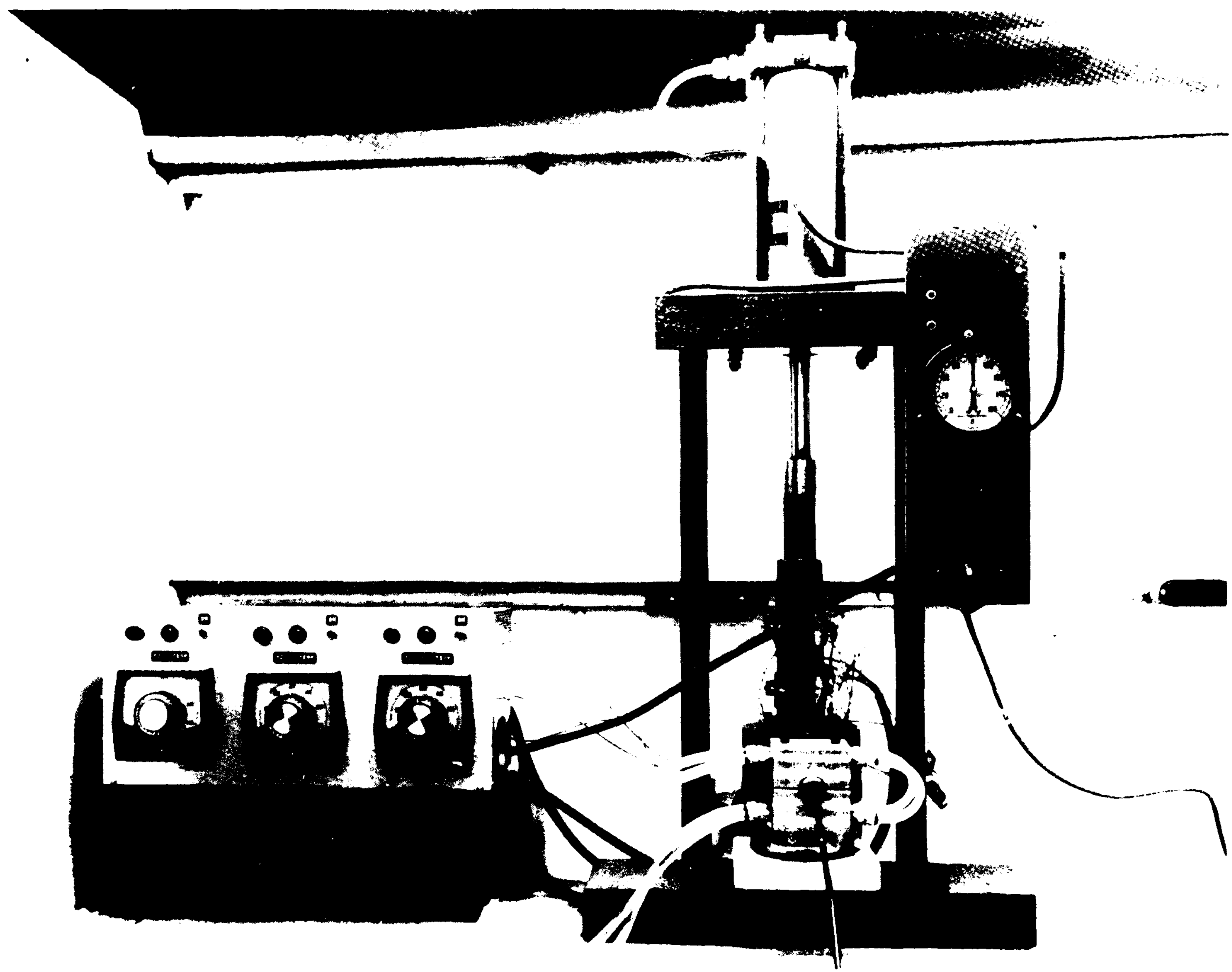


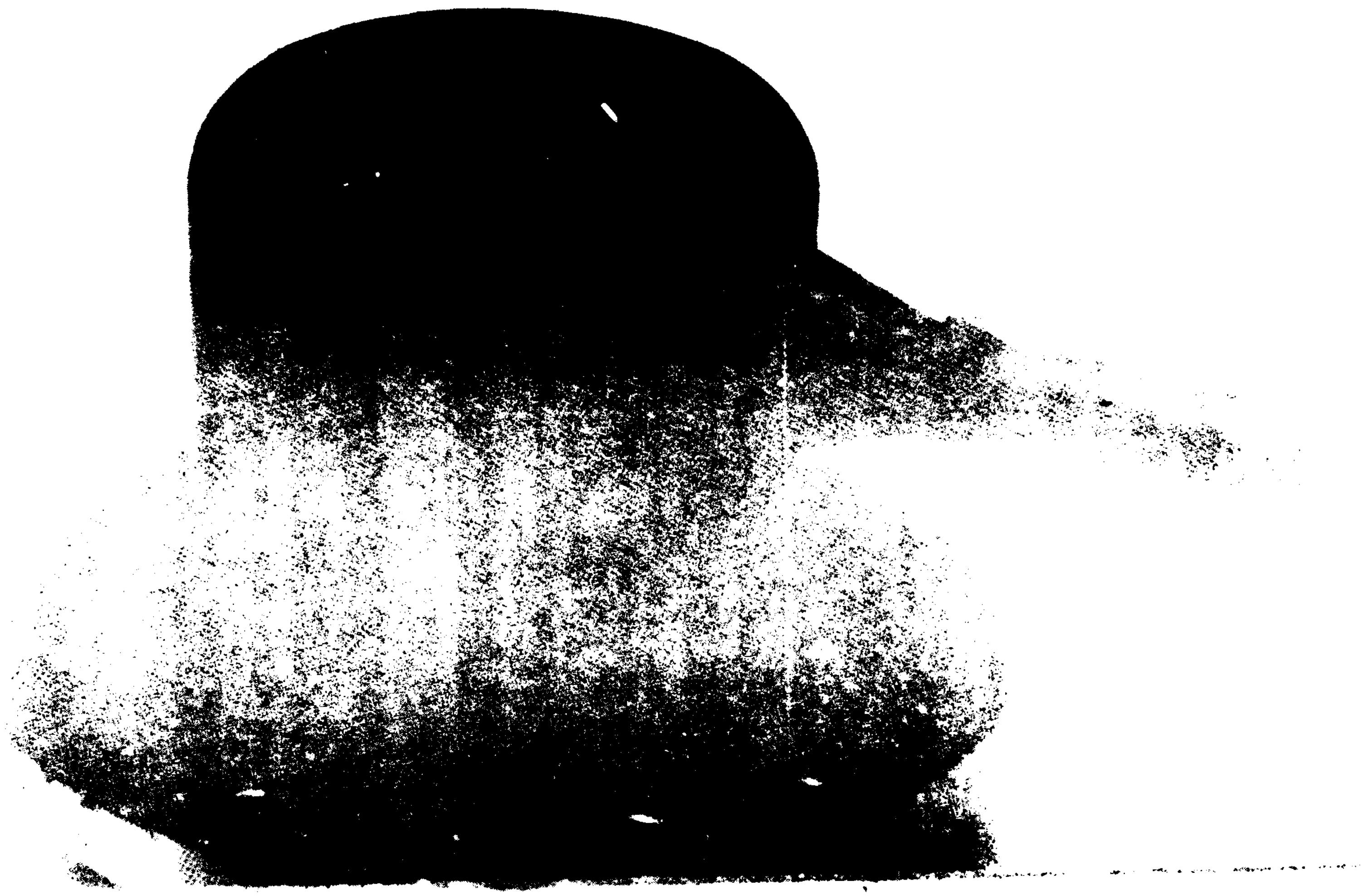
FIGURE 10-23 EPDM COMPOUND MOLDING APPARATUS

10.12.2 (Continued)

Mold temperatures are regulated by three proportioning controllers; one for the base flange, one for the mold, and one for the reservoir. These control eight heaters through three thermocouples mounted on the mold assembly. The press is pneumatically actuated to allow for an automatic transfer process and ease of regulation of the mold pressure during the cure cycle. Both the temperature controller and the molding press were designed specifically for AN/BRA-8 cable termination.

The molding procedure starts with the loading of 5 ounces of EPDM compound into the reservoir and developing a solid charge by applying air pressure to the press. The entire mold assembly is the preheated to 200°F. This softens the EPDM to allow for transfer of the compound to the mold cavity at a pressure of 600 P.S.I. Transfer time is a function of compound viscosity, but on the average it takes 35 minutes to fill the cavity. Once the compound has been transferred, 1000 P.S.I. is applied to pack the mold cavity and eliminate all air pockets. The temperature controllers are now reset to 285°F for the reservoir, 295°F for the mold, and 310°F for the base flange. The mold pressure is set to 740 P.S.I. Once the temperatures have stabilized, the cure cycle is started and the EPDM compound is cured for 40 minutes. At the completion of the cure cycle, the temperature controllers are turned off and the mold assembly is allowed to cool slowly. When the temperature of the mold assembly is below 200°F, the finished termination is removed from the mold, see Figure 10-24.

This molding work is presently being conducted by the G.W. Dahl, Company, Bristol, RI.



WESTCO

FIGURE 10-24 [illegible] CABLE [illegible]

10.13 Polyurethane Rubber Molding Cable Glands

Cable glands used to seal outboard cables as they enter transducers and hydrophones are normally provided with neoprene or polyurethane molded cable boot seals. The procedures which follow were prepared at Electric Boat Division for molding high and low frequency transducer cable glands for the TRIDENT submarine. The procedures are taken from Reference 10-19. In this case, polyurethane rubber is used to provide the cable boot seal to the polyurethane jacketed outboard cables. The procedure which follows covers the low frequency transducer. The high frequency transducer cable gland is molded in a similar manner.

10.13.1 Cable Preparation

The following procedures are to be followed in preparing the cables for molding to the transducer cable glands.

The 1PR-16 TRIDENT cables are jacketed with polyurethane, not neoprene.

1. Carefully remove the outer cable jacket from the end of the cable with a knife or a razor-bladed tool. The jacket removal length should be in accordance with Figure 10-23.

NOTE

CHECK CONDUCTOR INSULATION FOR NICKS AND SCRATCHES.

10.13.1 (Continued)

2. Wipe the end of the cable jacket for an approximate one-foot length with methyl ehtyl ketone. Roughen the cable jacket in the area to be bonded with a 60 mesh abrasive cloth. See Figure 10-25 to determine the roughening length. Lightly wipe the area of the polyurethane cable jacket with methyl ethyl ketone.

10.13.2 Cable Gland Cleaning and Sandblasting

1. Check the cable gland to see that it conforms to the applicable drawing prior to starting this phase of the procedure.

NOTE

CHECK THE O-RING GROOVE AGAIN FOR NICKS AND SCRATCHES.

2. Vapor degrease the cable gland in trichloroethane. Total elapsed time between initial vapor degreasing and sandblasting should not exceed 24 hours. If this period is exceeded, degrease the gland again.
3. Mask all areas not to be sandblasted as noted in Figure 10-26.
4. Sandblast the unmasked area with a clean, dry, 80 mesh silica sand. Use new grit if cleanliness and dryness are questionable. Blow off residual grit and remove the masking tape from the shell.

NOTE

SANDBLASTING APPARATUS SHALL PROVIDE AN AIR NOZZLE WITHIN THE UNIT TO ALLOW BLOWING THE SANDBLASTED COMPONENTS FREE OF RESIDUAL GRIT. THE AIR MUST BE FIL-

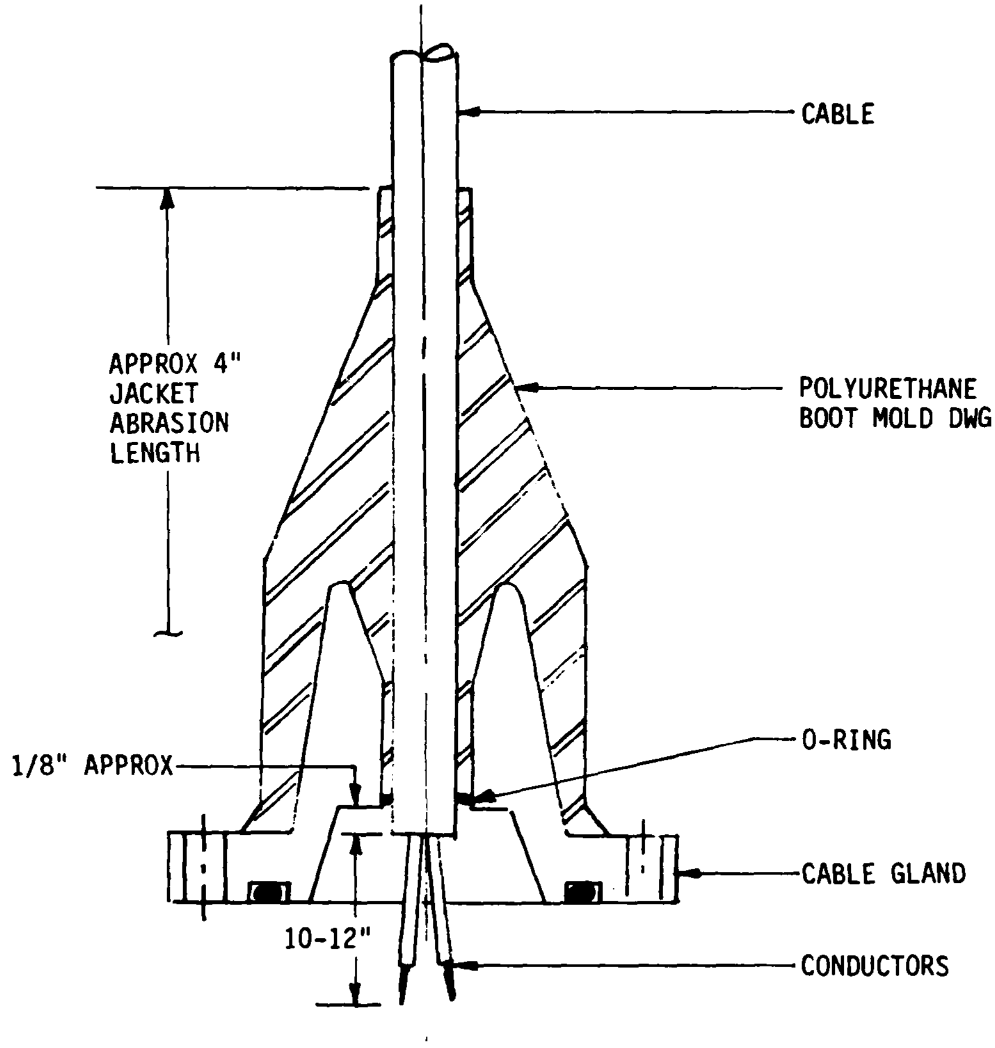


FIGURE 10-25 LOW FREQUENCY TRANSDUCER CABLE GLAND ASSEMBLY

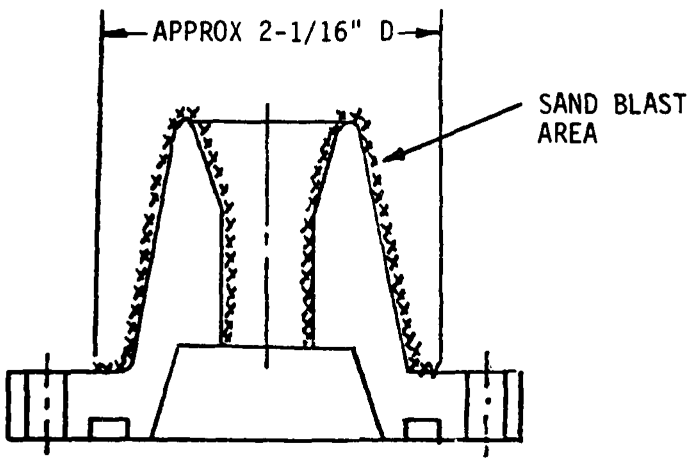


FIGURE 10-26 L.F. TRANSDUCER CABLE GLAND SANDBLAST AREA

10.13.2 (Continued)

NOTE

TERED AND DRY. INSPECT AND REPLACE FILTER AT APPROPRIATE INTERVALS TO AVOID CONTAMINATION.

5. Vapor degrease the cable gland again. Total elapsed time between sandblasting and final degreasing should not exceed 4 hours. If this period is exceeded, sandblast the shell once again as noted in the above steps.

NOTE

DO NOT TOUCH THE PREPARED AREA OF THE CABLE GLAND. IF THIS HAPPENS, THE GLAND MUST BE VAPOR DEGREASED ONCE AGAIN. PLACE THE CLEAN ASSEMBLY IN A SEALED CONTAINER WHERE THE GLAND WILL NOT BE TOUCHED OR CONTAMINATED.

10.13.3 Cable Gland Priming

The cable gland should be primed just prior to the molding operation and within four hours of final degreasing. Using a dry, oil-free, soft hairbrush, apply a thin uniform coat of the primer to the sand-blasted area. Primer must be applied within two hours of mixing. Allow the primer to dry one hour at room temperature. If the surface becomes contaminated or encapsulation has not been done within four hours after priming, the gland must be recleaned and sand-blasted.

10.13.3 *(Continued)*

NOTE

PRIMED SURFACES SHOULD NOT BE TOUCHED WITH FINGERS OR CONTAMINATED IN ANY OTHER WAY.

10.13.4 Cable Jacket Preparation

Following the roughening of the cable jacket, wipe the roughened area with methyl ethyl ketone (MEK). Allow the MEK to dry for a minimum of one half hour and a maximum of four hours.

10.13.5 Mold Preparation

Prior to molding a cable gland assembly, the following markings must be placed in the mold.

1. Markings on Boot - The boot manufacturer's markings must appear on the exterior molded section of each molded cable gland. Markings shall consist of:

   (a) Date molded (month, year, (for example 12-78)).

   (b) Manufacturer's symbol or trademark (GD/EB).

2. Markings shall be a part of the molded boot, enclosed 1/8" minimum lettering, legible, and located so as not to affect the function of the molded boot. Use 0.015" thick aluminum tags and shear around desired imprint. Reverse imprinted strips and bond to mold cavity with contact cement.

3. Apply a light coat of DC-20 (duluted 3 to 1 in hexane) to the mold cavities.

10.13.5 (Continued)

4. Preheat the mold assembly to 150°F just prior to use.

10.13.6 Molding Compound Preparation

The polyurethane molding compound to be used in fabricating transducer cable gland boots must be qualified to MIL-M-0024041. The category A, Type I, polyurethane should be used.

10.13.7 Molding the Transducer Cable Glands

The following procedures must be closely followed to assure properly molded connectors:

1. Install the cable in the back end of the cable gland.
2. Place an O-ring (see Figure 10-24) over the end of the cable jacket and force it into the bore of the cable gland as shown in the figures. (The O-ring will seal the polyurethane).
3. Assemble the mold halves about the cable gland. Fasten (as applicable) the cable gland to the mold.
4. Preheat the mold for 15 to 30 minutes at 180°F ± 5°F.
5. Remove the mold from the heat source. Remove the mold cover exposing the cable gland, but having it securely located within the mold base.

10.13.7 (Continued)

6. Take a 6 ounce thawed cartridge of polyurethane and wipe it dry and expel any air trapped under the plunger with a small screwdriver or round rod. Install the appropriate nozzle on the cartridge and place it in a pressure sealant gun.

7. Fill the inside of the cable gland with polyurethane.

8. Assemble the mold cover on the mold base while keeping the mold upright. Bolt the halves together.

9. Place the nozzle of the sealant gun in the fill hole and inject the polyurethane into the mold using 60 pounds of air pressure. Fill the mold with the compound until the level of the compound exudes from the vent holes. Withdraw the nozzle slowly from the inspection port keeping the pressure on the gun to assure that the injection port will be filled with the polyurethane compound. Plug the injection port with the mold plug provided. Allow mold to stand for a few minutes and screw in mold plug for a few more turns.

10. Heat the mold at $180^{o}F \pm 5^{o}F$ for six hours to cure the polyurethane.

NOTE

MOLDED CABLE GLANDS CAN BE REMOVED FROM THE MOLD AT THE END OF THREE HOURS IN A $180^{o}F$ OVEN BUT MUST BE REPLACED IN A $180^{o}F$ OVEN FOR AN ADDITIONAL THREE HOURS.

10.13.7 (Continued)

11. After curing the compound, allow the mold assembly to cool. Extract the molded cable gland from the mold.

12. Trim the compound flashing from the molded boot with a razor blade or small scissors.

13. Visually inspect the molded cable gland assembly.

14. Be sure to place protective cover material back on the front face of the cable gland following inspection.

10.14 Cable End Seal Preparation

At times, requirements arise for fabricating cable harness assemblies with connectors wired and molded to only one end of the cable. In most cases, the other end of the cable is end sealed to allow hydrostatic pressure testing. The following procedure can be used to seal neoprene, polyurethane, or polyvinyl chloride jacketed cables. Butyl or polyethylene jacketed cables should be end sealed with processes established for molding at the connector end. The Raychem Corporation, Menlo Park, CA, has also developed a product, Thermofit End Caps, which can be used to end seal polyethylene jacketed cables.

10.14.1 Preparation of the Cable End Seal

1. Cut and square the cable ends.
2. Wash the cable jackets in the area to be bonded with methyl ethyl ketone. Roughen the cable jacket in the mold area with a coarse abrasive cloth or file.
3. Apply a coat of the cable primer for polyurethane on one inch of the roughened cable jacket. Allow the adhesive to dry 1/2 hour minimum, 4 hours maximum.
4. Slip a three-inch long piece of shrink tubing over the cable as shown in Figure 10-27. Hold firmly in place and apply heat uniformly around the heat shrinking area using a hot air gun (500°F minimum). The vent should be wide open and the gun held about two inches from the tubing in the heat shrinking area. Do not shrink the tubing onto the primed cable area.

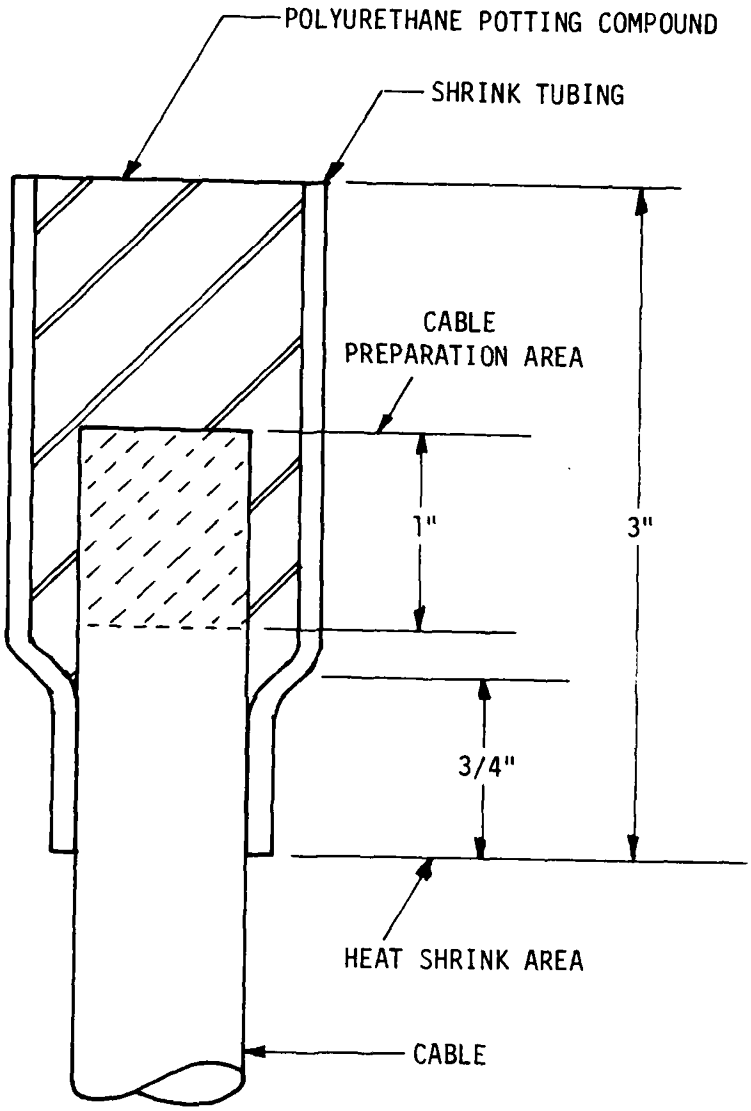


FIGURE 10-27 CABLE END SEAL

10.14.1 (Continued)

5. Allow the shrink tubing to air cool.

6. Inject the polyurethane rubber compound into the cavity formed by the shrink tubing fitted on the end of the cable.

7. Cure the polyurethane for eight hours at $150^{o}F - 160^{o}F$.

10.15 Outboard Cable Harness Fabrication Record

An outboard cable harness fabrication record is provided in Table 10-5 as a typical example of a fabrication record. The harness supplier should prepare a record of harness fabrication and keep these records following fabrication. The record depicted in Table 10-5 was prepared by the Electric Boat Division for the TRIDENT Submarine Outboard Cables, Reference 10-20.

TABLE 10-5

OUTBOARD CABLE HARNESS FABRICATION RECORDS

Ship ____________ Wiring and Molding Procedure No. ________ Rev. ____

Cable No. ____________ Applicable Wiring Diagram ____________ Rev. ____

Step	Technician Initials	QC Initials	Date	Remarks
Work Area Clean	____			
Cable				
Cable Inspected	____			
Cable Type	____			____
Cable Length	____			____
Cable Jacket Removal	____			
Cable Insulation Removal	____			
Shield Termination	____			
Conductors Undamaged	____			
Plug or Receptacle - End A				
Type ____________	Manufacturer ____________			
Connector Inspected	____			
Contacts Inspected	____			
Key/Keyway Checked	____			Time
Initial Vapor Degrease	____	____	____	____
Silica Blast	____	____	____	____
Final Vapor Degrease	____	____	____	____
Sleeve Protected	____	____		
Wiring				
Conductors Proper Length	____	____		
Proper Crimping Tool	____	____		
Crimping Satisfactory	____	____		
Soldering Satisfactory	____	____		
Contacts Insulated Properly	____	____		
Contacts Installed Properly	____	____		
Continuity Satisfactory	____	____		
Insulation Resistance Satisfactory	____	____		
Molding				
Plug Assembled	____	____		
Jacket Roughened/Primed	____	____	____	Time ____
Jacket Adhesive Expires	____	____	____	
Connector Primed	____	____	____	Time ____
Connector Primer Expires	____	____	____	
Connector Adhesive Applied	____	____	____	Time ____
Connector Adhesive Expires	____	____	____	
Mold Properly Marked	____	____	____	
Mold Release Applied	____	____		
Urethane Compound Expires	____	____	____	
Assembly Potted/Cured	____	____		
Connector Trimmed Properly	____	____		

TABLE 10-5

(Cont'd)

Step	Technician Initials	QC Initials	Date	Remarks
Assembly				
O-Ring/Groove/Seal Surfaces Inspected	____	____		
O-Ring Cure Date	____	____	____	
O-Ring Lubricated/Installed	____	____		
Split Washer Installed	____	____		
Plug or Receptacle - End B				
Type ____	Manufacturer ____			
Connector Inspected	____	____		
Contacts Inspected	____	____		
Key/Keyway Checked	____	____		Time
Initial Vapor Degrease	____	____	____	____
Silica Blast	____	____	____	____
Final Vapor Degrease	____	____	____	____
Sleeve Protected	____	____		
Wiring				
Conductors Proper Length	____	____		
Proper Crimping Tool	____	____		
Crimping Satisfactory	____	____		
Soldering Satisfactory	____	____		
Contacts Insulated Properly	____	____		
Contacts Installed Properly	____	____		
Continuity Satisfactory	____	____		
Insulation Resistance Satisfactory	____	____		
Molding				
Plug Assembled	____	____		
Jacket Roughened/Primed	____	____	____	Time ____
Jacket Adhesive Expires	____	____	____	
Connector Primed	____	____	____	Time ____
Connector Primer Expires	____	____	____	
Connector Adhesive Applied	____	____	____	Time ____
Connector Adhesive Expires	____	____	____	
Mold Properly Marked	____	____	____	
Mold Release Applied	____	____		
Urethane Compound Expires	____	____	____	
Neoprene Applied Properly	____	____		
Assembly Potted/Cured	____	____		
Connector Trimmed Properly	____	____		

TABLE 10-5

(Cont'd)

STEP	Technician Initials	QC Initials	Date	Remarks
Assembly				
O-Ring/Groove/Seal Surfaces Inspected	______	______		
O-Ring Cure Date	______	______	______	
O-Ring Lubricated/Installed	______	______		
Split Washer Installed	______	______		
Testing				
Socket Contacts Inspected	______	______		
I.R. Test Recorded	______	______		
Pressure Test Performed	______	______		
Voltage Test Recorded	______	______		
Continuity Test Performed	______	______		
Cable Assembly Cleaned	______	______		
Connector Caps Installed	______	______		
Assembly Packaged/Tagged	______	______		

Technician Signature ______________________ Date ____________

QC Signature ______________________ Date ____________

Foreman Signature ______________________ Date ____________

NOTE:

PLACE N/A IN TECHNICIAN INITIAL BLOCK WHERE THE WIRING AND MOLDING OPERATION STEP IS NOT APPLICABLE.

10.16 Outboard Cable Harness Wiring and Molding Personnel Qualification

10.16.1 General

The technician who performs the inspection, wiring, molding and testing operations in fabricating a pressure-proof harness is the key to a reliable harness fabrication. The technician must handle all components (cables and connectors) very carefully at all times. He must use extreme care to not nick conductors. The contacts must be attached to the connectors in a very exacting fashion. Care must be exercised in mixing potting material as well as molding the connector assembly. Once molded, the harness assembly must be non-destructively tested using great care not to damage the assembly in handling.

In many respects, the technician must serve as his own inspector. There are no economical or sure methods for checking assembled harnesses for nicks in conductors, or voids in potting compounds except those compounds that are transparent (amber polyurethane) X-ray techniques are available but have not exposed possible problem areas with any degree of certainty.

The best method for assuring properly fabricated, reliable harness assemblies it to make use of well trained, conscientious, capable technicians who will closely follow prescribed procedures.

10.16.2 Qualification

The technician qualification should be based on the successful completion of a short course embodying all of the personnel information contained in the Manual.

10.16.3 Course Description

The study course for technician qualification should include the following work topics:

Subject		Approximate Days
(a)	Manual familiarization	1/2
(b)	Specification familiarization	1/2
(c)	Safety precautions	1/4
(d)	Cable inspection	1/4
(e)	Connector inspection	1/4
(f)	Preparation of molding compounds	1/4
(g)	Preparation of cables	1/2
(h)	Soldering and crimping conductors to contacts	1/4
(i)	Potting plug inserts with polyurethane	1/4
(j)	Preparing the plug and receptacle sleeve	1/4
(k)	Assembling and molding the connector	1-3/4
(l)	Potting cable end seals	1/2
(m)	Inspection and test of fabricated harnesses	1-1/2
(n)	Test	1

From the above it is seen that an 8-day course should be mandatory in qualifying a technician for fabricating pressure-proof harnesses.

10.16.4 Course Working Area Requirements

The course should be conducted in a location where harness wiring and molding facilities, tools and materials are available.

10.16.5 Course Material Requirements

The following material should be furnished to each participant to complete the projected scope of the source.

(a) Manual Familiarization
One copy of each Manual should be given to each participant.

(b) Specification Familiarization
The following specifications and drawings should be available during the course: MIL-M-24231, CPG 1027, MIL-C-24217, MIL-C-22539, MIL-C-915, and Drawing 2630-077 and D.G. O'Brien Drawing C17D5005G.

(c) Cable Inspection
1. Two foot samples of cables.

(d) Connector Inspection
1. Plug/receptacle assembly samples.

(e) Preparation of Molding Compound
1. Polyurethane, adhesives and primers.

(f) Preparation of Cable Ends
1. Cable samples.

(g) Soldering Conductors to Contacts
1. Cable samples.
2. Solder.
3. Socket contacts.

10.16.5 (Continued)

(h) Prepotting Socket Inserts with Polyurethane
   1. Aligning plugs
   2. Socket contacts
   3. Polyurethane

(i) Preparing the Plug Sleeve
   1. Metal primer
   2. Tape
   3. Sandblasting grit

(j) Assembling and Molding the Cable to the Connector
   1. Cable
   2. Plugs/Receptacles
   3. Molds
   4. Polyurethane

(k) Potting Cable End Seals
   1. Shrink tubing
   2. Solvent
   3. Polyurethane

(l) Inspection and Test of Harness
   1. Socket contact weight gage
   2. Megohmmeter
   3. Hydrostatic pressure vessel
   4. Harness assembly

(m) Test
   1. Written and oral

NOTE

THE ABOVE MATERIAL WAS EXCERPT' FROM REFERENCE 10-20.

REFERENCES

10-1 NAVSHIPS 0962-022-2010, "Molding and Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables".

10-2 NAVSHIPS Drawing NR-1-302-2663185, "Wiring, Molding, Testing, Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators", Naval Ship Engineering Center, Washington, D.C.

10-3 NAVSEA Drawing 815-1197381, "Connector, Electrical, Watertight, Submarine, Wiring and Molding Procedures (MIL-C-24217)".

10-4 NAVSEA Drawing 815-1197377, Sheets 2 and 3, "Connector-Watertight - 5 Pin, Wiring and Molding Procedures for 1SWF-2 Cables".

10-5 NAVSEA Drawing 815-1197380, Sheets 1 and 2, "Plug for FSS-2 Cable-Wiring and Molding Procedures".

10-6 Electric Boat Division Specification 2580, "Rubber Stock, Molding, Uncured".

10-7 NAVSEA S9074-AA-MMO-010/DVS-3, 4, "Technical Manual - Fabrication, Installation, Maintenance and Repair, Outboard Cable Harness Assembly Turtle (DSV-3) Sea Cliff (DSV-4)", Prepared by the Mare Island Naval Shipyard, Naval Sea Systems Command, 1/1978.

10-8 NAVSEA Drawing 4554201, "Cable Head Assembly", Prepared by Naval Weapons Support Center, Crane, Indiana.

REFERENCES
(Con 'd)

10-9 NWSC Document No. 7055-0019, "Assembly, Inspection and Test Procedures for the AN/BQR-21 Hydrophone Staves.

10-10 NWSC Drawing No. 4551226, "Vulcanizer Rubber, Butyl, Specification Control Drawing".

10-11 NWSC Drawing No. 5218179, "Interface Rubber, Vulcanizer, Specification Control Drawing".

10-12 Zuraw, E.A., "Bonding Polyethylene to K-Monel Metal", Electric Boat Division Report No. U 440-74-042, May 9, 1974 (TRIDENT Document No. AB1700).

10-13 Zuraw, E.A, "Polyethylene to Metal Bonding - A Literature Review - Phase I", EBDvision Report No. U 440-73-030, February 27, 1973.

10-14 Zuraw, E.A., "Polyethylene to Metal Bonding - Evaluation of Potential Methods - Phase II", EBDivision Report No. U 440-73-112, November 15, 1973.

10-15 Zuraw, E.A., "Elements of Bonding Polyethylene to K-Monel Metal for Underwater Electrical Applications - Phase II", EBDivision Report No. U 440-75-039, April, 1975.

10-16 Kraimer, R.C., & Orr, J.F., "The Use of Ethylene Propylene Diene Monomer (EPDM) Molded Connectors on AN/BRA-8 Towed Antenna Arrays".

REFERENCES

(Cont'd)

10-17 "Final Report on Materials Bonding", Debell & Richardson (now Springborn Laboratories), Prepared for ONR, Project No. 6041.1, April, 1973.

10-18 "Final Report on Cable Splicing", Debell & Richardson (now Springborn Laboratories), Prepared for NUSC Project No. 6035.6, January, 1976.

10-19 Haworth, R.F., "Procedures for Molding, Inspection and Testing Transducer Cable Glands for TRIDENT Submarines", EBDivision Document No. CPG 1326, November 21, 1978.

10-20 Electric Boat Division CPG 1060, "Procedures for Wiring, Molding, Inspection and Testing Pressure-Proof Electrical Connectors for TRIDENT Submarines".

10-21 Electric Boat Division, CPG 1022, "Penetrator Electrical, TRIDENT Submarines".

(Blank)

SECTION 11

CABLE SPLICING AND REPAIR METHODS

LIST OF FIGURES

LIST OF TABLES

11.1 Introduction

A cable splice is a mechnical joint made in a cable which provides electrical continuity of the enclosed conductors or provides electrical distribution from the conductors of one cable to the conductors of several other cables. The conductors are most often joined by a crimp type butt splice connector, but in some instances the connector can be of the solder variety. Each splice connector is insulated by any of several means from the other splice connectors surrounding it to prevent electrical short circuiting. If the cable splice contains a multitude of conductors, some method of spacing is usually employed to prevent the insulated conductors from migrating during the application of outer wrappers or during the molding operation. An adhesive system is usually applied to the cable ends to ensure a bond between the cable and the molding compound or wrapper which forms the external covering or body of the splice. It is this body, acting as the barrier, which seals the splice from the sea water environment. The splicing operations which are discussed here are designs intended to resist sea water immersion. The same techniques are used, however, in designing and molding splices used for the inboard submarine environment.

The term splice, unfortunately, has inherited the connotation of being a temporary measure for joining electrical cables. It has come to imply a stop gap field operation with all the undesirable features that can result when carried out under emergency circumstances. As a result, cable splicing has been looked upon with distrust even though when properly done it can be of great advantage. Much of cable splicing's bad heritage is due to the fact that in the past, proper materials and tools were not readily available. The operation was done on a makeshift basis with questionable reliability.

11.1 (Continued)

This situation has led to the recognition of needed improvements in this area, resulting in the development of specialized materials and tools. This has allowed the designer not only to use the cable splice as an approved means of repair, but also to use it during original manufacture of cable harnesses. Under the latter circumstance, environmental conditions can be controlled, thereby eliminating them as a quality control variable. Materials used in the splice manufacturing process can be properly stored and controlled, and the actual molding is performed under closely regulated conditions. All of the above contribute to the increased reliability of cable splicing.

Field repair kits, specialized tools, and portable presses for compression molding, as well as innovative splicing concepts, have all contributed to increasing the reliability of cable splices conducted in the field. Environmental control in this situation still poses a problem since possible contamination of adhesives and cleaned surfaces is more likely to occur.

All factors considered, given the proper materials, equipment, and procedures and conducted under controlled conditions, the splicing of electrical cables can be achieved with a high degree of reliability. A properly fabricated splice should have the same pressure capability of the cable being spliced.

There are many advantages to be gained by employing cable splices in a submarine or surface ship outboard electrical cable system. Considerable cost saving can be realized when a multiple cable splice is substituted for an outboard distribution box. Connector hardware at the junction is totally eliminated and the number, size, and length of cables are kept to a minimum. This can result in considerable weight saving, yielding increased payload capability which is often a major problem with small, deep diving submersibles.

A good portion of the outboard electrical equipment is often supplied with its cable molded integral with its housing. When items with a short service life such as some transducers require replacement, it can be a time consuming and costly task, especially when long cable runs are involved. In cases such as these, equipment can be replaced by cutting its cable and splicing in the cable of the replacement components. This would eliminate the task of unbonding and sorting out the electrical cable from its cable pan and disconnecting the cable plug at the hull penetrator and then repeating the above work when installing the new equipment.

A secondary benefit to be gained from the use of a cable splice placed near the equipment is the possible creation of a waterdam in the cable conductors. Many outboard cables in use on submersibles are assumed to be pressure-proof or anti-hosing. Past experience has shown, however, that this is not the case. Consequently, there are many instances of equipment flooding caused by a punctured or severed cable when a connector is not employed at the component. In order to create a positive waterdam at the conductors, it is necessary to use a special type splice connector similar to that described in References 11-1 and 11-2.

On the other hand, splices in cables are not without their disadvantages. One possible fault that can arise as a result of a splice is increased circuit electrical resistance. This can be caused by improper crimping of the splice connector or oxidation of the components being crimped.

11.1 (Continued)

Electrical circuits sensitive to changes in cable impedance (usually radio frequency) should not be spliced. The presence of a splice in this type of circuit alters the capacitance and impedance to such an extent that serious deterioration of the signal within the cable can result.

Shielded cables can present splicing problems when a multitude of shields and conductors exist. Staggering of splice connectors must be accomplished to avoid too large a splice diameter. This can only be achieved by increasing the length of the splice. Migration of conductors in multiconductor splices can also become a problem since interconductor distance is small. Conductor spacers or positioners must be used, but often their geometry can become quite complex, adding to the time required to perform the splice.

Another disadvantage which must be considered in the case of multiple cable splices is the extensive damage which can result if leakage occurs on the multiple cable side of the splice. For example, if a one-cable-into-three-cable splice were to develop a leak on the three-cable side of the splice, three cables or circuits would be affected rather than one if separate cables were used for each circuit. Furthermore, if no waterdam were present at the equipment, damage could be quite widespread since more than a single component could become flooded.

11.1 (Continued)

The cable jacket materials encountered in splicing outboard electrical cables are synthetic rubbers, chloroprene (neoprene), and chlorosulfonated polyethylene (Hypalon); polyurethanes; polyvinyl chlorides (PVC); and polyethylene. A general understanding of the properties of the above materials and the type of service each will be subjected to is required for an intelligent choice of a splice system to be used. There are several basic types of splicing techniques available, each requiring specific tools and equipment in order to execute properly. These are outlined and discussed in the following paragraphs.

11.2 Tape Splice

This is undoubtedly the simplest and quickest splice to make up of all those used to join electrical cables. Alvin personnel at the Woods Hole Oceanographic Institute also report that this type of splice is reliable.

Conductors are joined with crimp connectors; or soldered. Three thin layers of "Scotch Fil" insulation (manufactured by 3M Company) material are applied over the spliced area. The tape is obtainable in one-inch wide rolls. For this application the tape is split into one-half inch wide strips and carefully stretched as it is evenly and uniformly wrapped around the splice. A 50 percent overlay is used in wrapping. The tape is extended two or three inches beyond the bared wire on either side of the splice. Then two layers of "Scotch 88" vinyl electrical tape (3M Company) are applied over the initial tape layer. Here again, the tape is split into one-half inch strips and overlapped by 50 percent. Finally, the spliced area is covered with a heavy walled shrink tubing which provides mechanical strength and protection. (See Figure 11-1).

One note of caution is that the tapes must be applied and stretched evenly. A right-angle kink in the splice has resulted following a deep dive when the tape was unevenly applied. When a properly made splice is subjected to high hydrostatic pressure, the Scotch Fil tape amalgamates into a solid mass.

The Naval Research Laboratory, Orlando, Florida, also makes use of a tape splice. They use the 3M "Scotch 88" vinyl tape over the splice area and cover this tape with a Plymouth Rubber Co., 104 Revere Street, Canton, MA, 02121, type TL-192 tape.

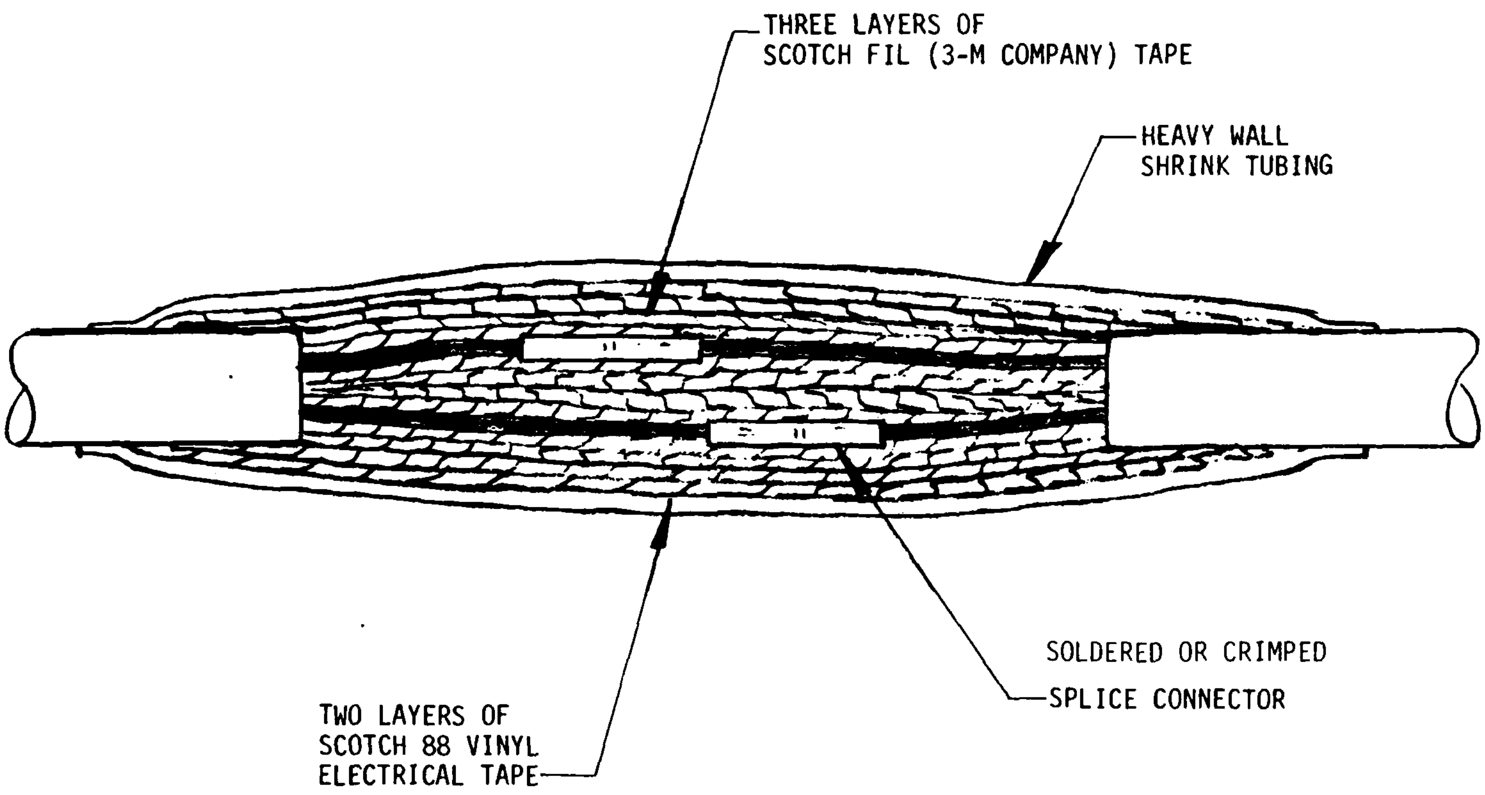


FIGURE 11-1 TAPE SPLICE

11.3 Epoxy Splice

The epoxy splice is a technique using a low cost mold apparatus. It consists of an epoxy resin compound, a clear arcylic plastic tube which serves as the mold for the splice, and two end caps with filler or vent holes. Figure 11-2 shows a cross section of a spliced cable using the epoxy system.

The portion of the cable within the splice should be clearly marked, solvent cleaned, and roughened with sandpaper. It is of upmost importance to keep this area from becoming contaminated once it is prepared, otherwise a proper bond will not be possible. The end caps are fitted over each cable end and the body tube fitted over one end of the cable. To prevent leakage of the epoxy resin, the end caps must be trimmed to provide a tight fit against the cable jacket. When the proper fit is attained, the caps and body are slid down the cable, the splice is made, and the caps and body are positioned so that the splice is centered in the mold cavity. The mixed epoxy resin is then injected through the filler nozzle while the mold is slightly tilted to elevate the vent nozzle; this is done to minimize air entrapment. When the cavity is full, the mold is set in a horizontal position and allowed to cure.

This method provides a relatively simple means of effecting a cable splice. The splice is presently being used by NAVSEA (Reference 11-3) for joining connectors to already installed cable.

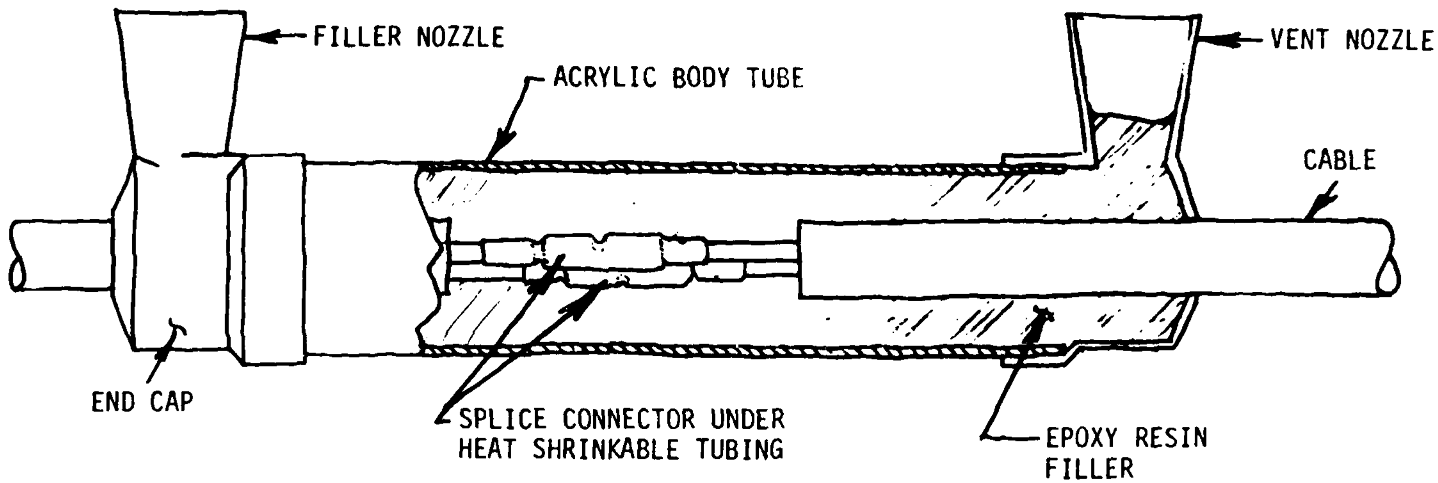


FIGURE 11-2 EPOXY SPLICE

11.4 Plastic Tubing Splice

This type of splice is shown in Figure 11-3 and can be seen to be quite simple in principle. The filler material is electrically non-conductive and the tubing is flexible, allowing the system to be pressure compensating.

A rubber tube is slid over one end of the cable to be spliced. The conductors are stripped, and shrink tubing is slipped over each conductor on one end of the cable. Splice connectors are then crimped to the conductors. The splice is then filled with a suitable mastic or uncured neoprene tape. The outside diameter of the splice is made a little larger than the cable diameter to insure a strong fit of the tubing over the splice. The tubing is slid over the splice using DC-4 silicone grease. The tubing is then clamped or string-tied to the cable to provide a compression rubber-to-rubber seal. Reference 11-4 notes that this quick type of splice has proven reliable at pressures up to 20,000 psi. This type of splice would have to be tested, however, to determine the effectiveness of the tubing-to-cable seal over long periods of service.

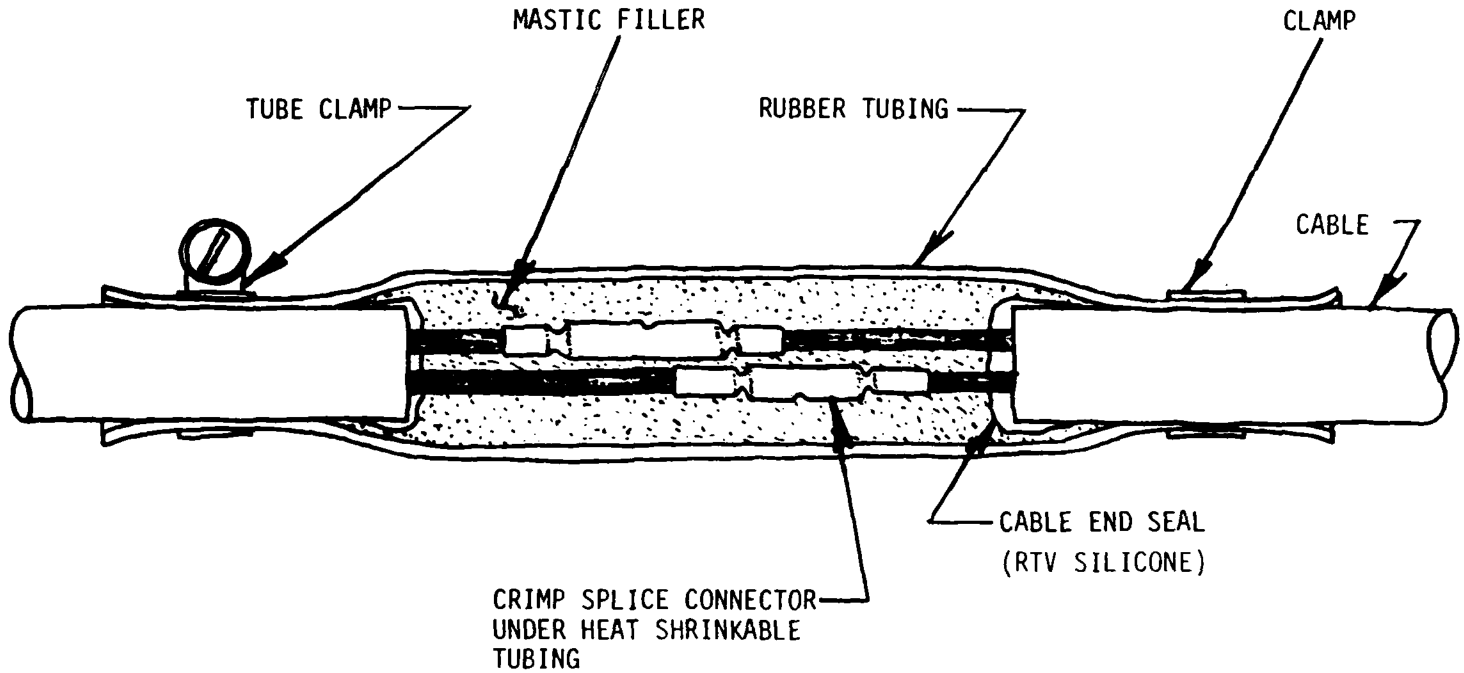


FIGURE 11-3 PLASTIC TUBING SPLICE

11.5 Shrinkable Tubing Splice

This is another type of splicing method which has been used with success on undersea communication cables. The depth at which these cables are laid is not known for certain, but it is estimated to be in the region of 1000 feet. The equipment has been operative for several years and appears quite reliable in this application.

The splice consists of a heavy wall sleeve of heat-shrinkable tubing coated on the inside surface with an adhesive which becomes soft when the tube is heated. The adhesive then flows into contact with the cable and splice constituents, filling most small voids. The same type of adhesive-coated, heat-shrinkable tubing is used to seal and insulate the individual wire splices. This is followed by semi-cured neoprene tape wrapping and the application of the outer adhesive-coated, heat-shrinkable tubing. Referring to Figure 11-4, the illustration shows the addition of optional tube clamps and/or cable end seals.

In effect, this type of splice provides a triple water barrier which should provide a good degree of reliability. This splice is rather stiff, however, and should not be subjected to bending. A plastic saddle to which the spliced portion of the cable could be anchored might prove a worthwhile adjunct to this design. The shrinkable tube-type cable splice is probably more reliable than the three previously discussed splicing systems. Reference 11-5 notes laboratory tests conducted on this type of cable splice.

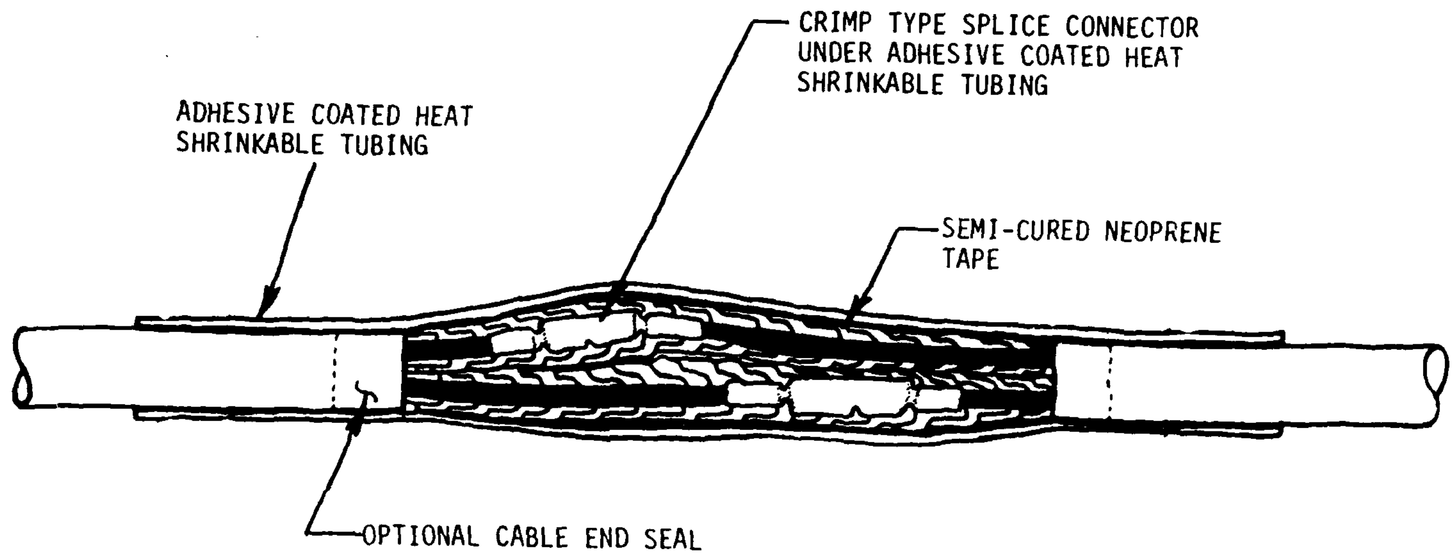
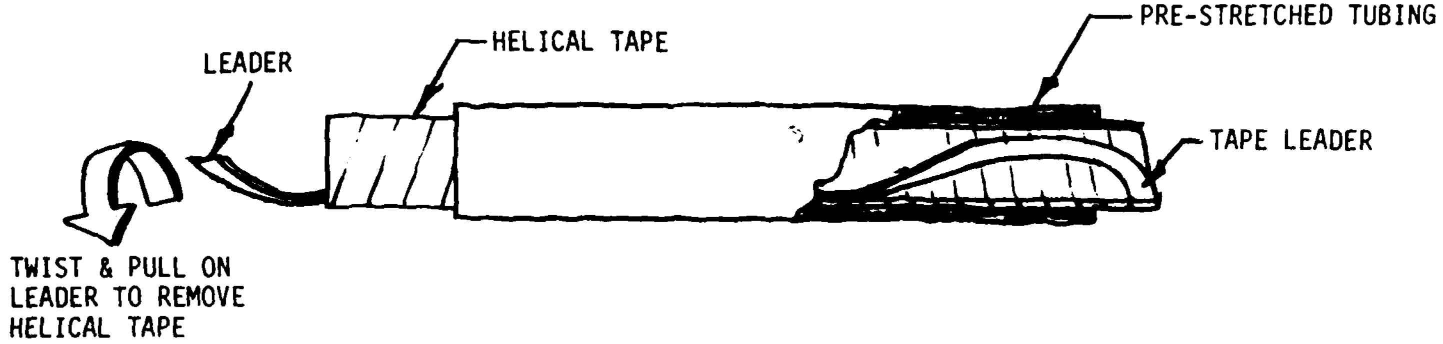


FIGURE 11-4 SHRINKABLE TUBING SPLICE

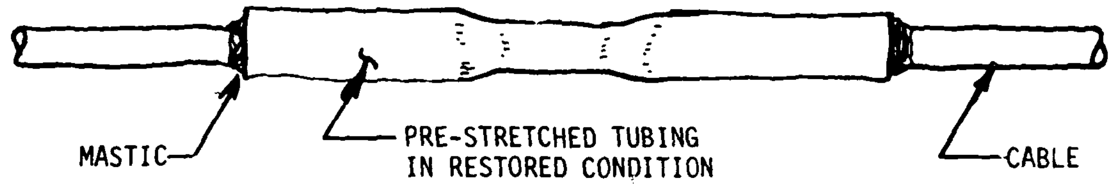
11.6 Mechanically Expanded Rubber Tubing Splice

This type of splice (shown in Figure 11-5) is performed using a proprietary kit which contains a length of pre-stretched tubing and a package of non-hardening insulating mastic (Reference 11-6). The tubing is unique inasmuch as it is held in its expanded attitude by a helical coil of flat plastic tape. The tape is so constructed that when it is wound in a helical pattern, its interlocking edges prevent if from colapsing. When the tubing is positioned over the prepared cable splice, the tape is removed by a simple peeling action of its leader. The tubing then reverts to its natural size, squeezing out excess mastic and completing the splice. The shrinkable ratio is about 2 to 1.

This splice is probably best suited for single conductor cables of relatively large diameter. Since this is a relatively new product, further testing for use in underwater applications is required prior to use of this design.



(A) CROSS SECTION OF PRE-STRETCHED TUBING
SYSTEM PRIOR TO INSTALLATION



(B) PRE-STRETCHED TUBING SYSTEM
ON FINISHED CABLE SPLICE

FIGURE 11-5 MECHANICALLY EXPANDED RUBBER TUBING SPLICE

11.7 Neoprene Rubber Molded Splice

This method provides one of the most reliable means of effecting an electrical cable splice. It also requires more tooling and equipment than any other method of splicing due to the nature of the material which covers and protects the splice. The splice's rubber jacket is vulcanized in place, essentially providing a continuation of the cable jacket. The result is as nearly integral a system as possible. In order to achieve the vulcanized rubber splice, however, sources of heat and compression are required, as well as a split metal mold, all of which require a capital outlay. The mold itself may cost several hundred dollars depending on its complexity. Figure 11-6 depicts a typical compression rubber splice mold.

The one major drawback to this system is that the technique involves a skill acquired only from experience. Packing of the mold with the unvulcanized stock must be done carefully, with the correct amount positioned in the proper locations. Insufficient rubber creates voids, and excessive rubber can result in an inordinate migration of the conductors within the mold, possibly degrading the cable electrical characteristics. Once the mold cavity is correctly packed, a proper balance of heat and compression must be maintained. Excessive mold compression with inadequate temperature or too short a compound softening time can contribute to excessive conductor migration.

In many cases of compression-molded splicing operations, procedures are used which provide instructions for fabricating a series of sheet metal templates which can be used as guides for cutting and shaping the uncured rubber stock to be packed into the mold cavity or wrapped around the splice components. Additionally, primer/adhesive systems are necessary to provide the bond to the cable jacket material.

11.7 (Continued)

A typical compression-molded rubber splice is shown in Figure 11-7, References 11-6, 11-7 and 11-8 detail compression-molded rubber splice work accomplished by the U.S. Navy.

The compression-molded rubber splice is one of the best methods available for making a reliable splice in an electrical cable. It may be better suited for deep submergence application when prepotted with a suitable epoxy compound as shown in Figure 11-8.

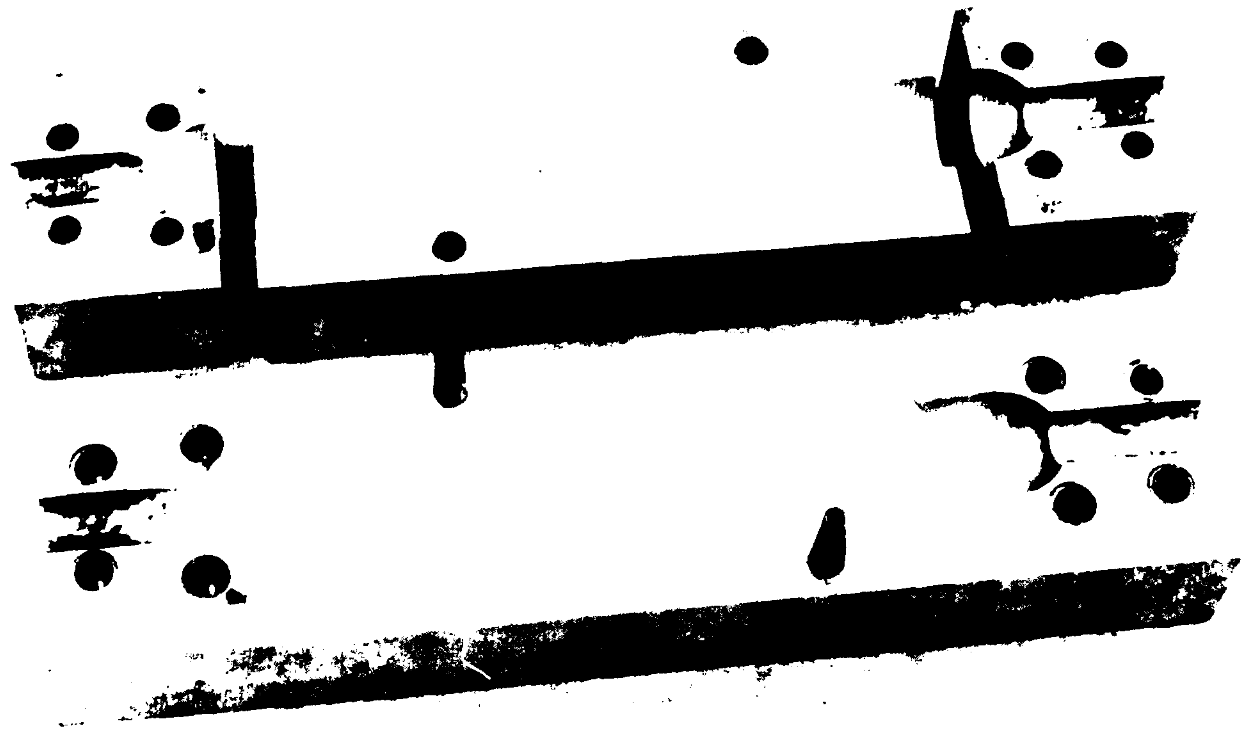
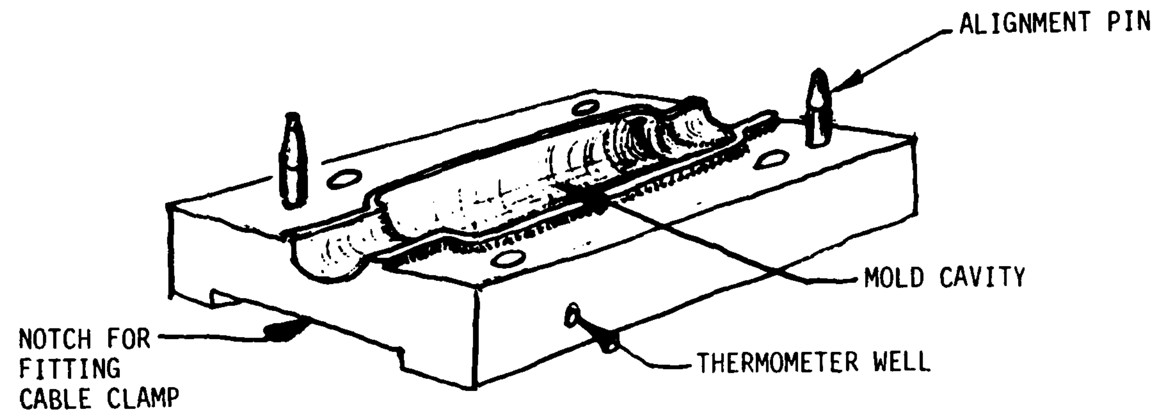
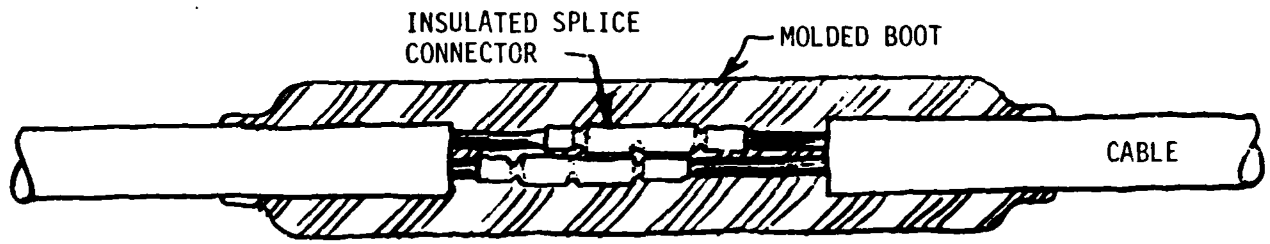


FIGURE 11-6 COMPRESSION RUBBER NEOPRENE SPLICE MOLD



COMPRESSION MOLD HALF (SHOWN
WITHOUT CABLE CLAMP)



CROSS SECTION OF A COMPLETED
COMPRESSION-MOLDED RUBBER SPLICE

FIGURE 11-7 COMPRESSION MOLDED NEOPRENE RUBBER SPLICE

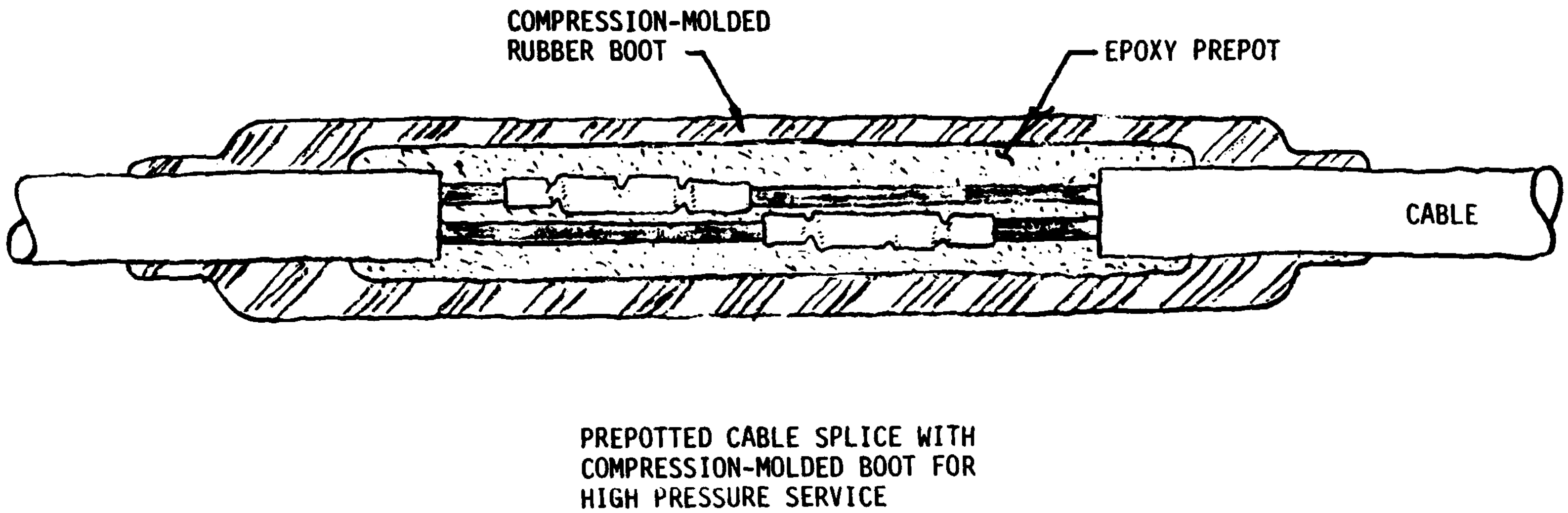


FIGURE 11-8 PREPOTTED COMPRESSION-MOLDED NEOPRENE CABLE SPLICE

11.8 Polyurethane Rubber Molded Splice

The molded polyurethane splice is quite similar to the compression-molded rubber splice with the exception that compression is not a required part of the molding procedure. This considerably simplifies the molding since a press is not required; also, the mold can be modified to reduce the cost. Molds can be manufactured from metal, but simple items such as plastic tubing can be used since the polyurethane molding compound is cast in place. Molds have been fabricated from heat-shrinkable tubing contracted on a mandrel. The expendable form generated in this way is then placed over the spliced area, sealed, and filled with the urethane compound.

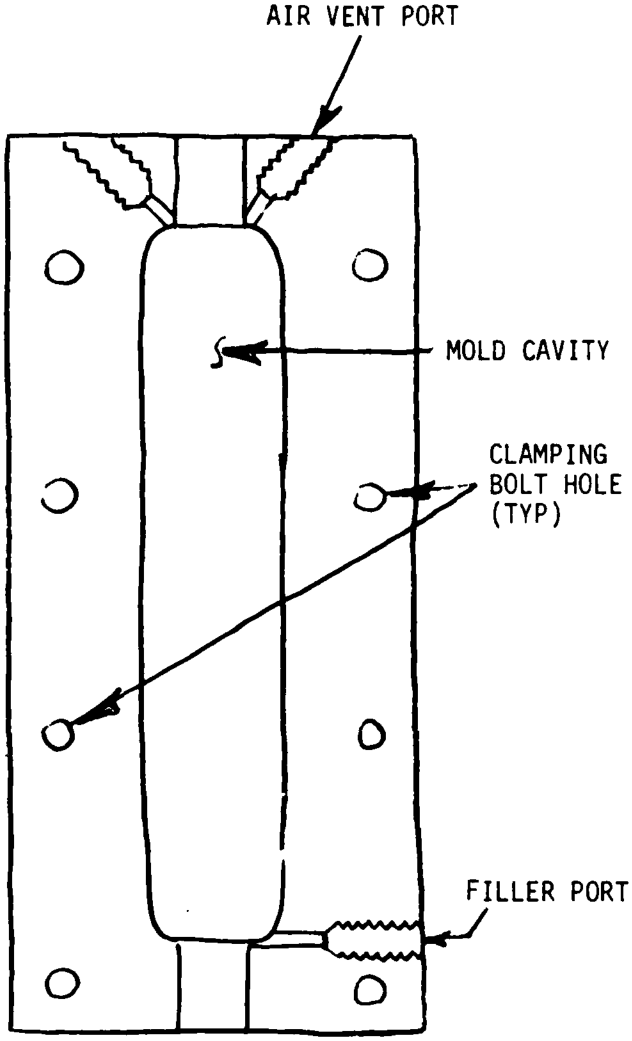
A temperature of between 150^{o} and 180^{o}F is required to cure the urethane within an 8-hour period. Polyester base urethanes should be avoided since these types have suffered hydrolsis in marine environment. Polyether base compounds per MIL-M-24041 are suitable for this application. They display very good resistance to sea water, oils, and fuels, and excellent abrasion resistance.

A disadvantage of this material is its short shelf life even when stored at temperatures of -100^{o}F. An unactivated, two-part compound is available, but it requires thorough mixing and degassing for consistent performance.

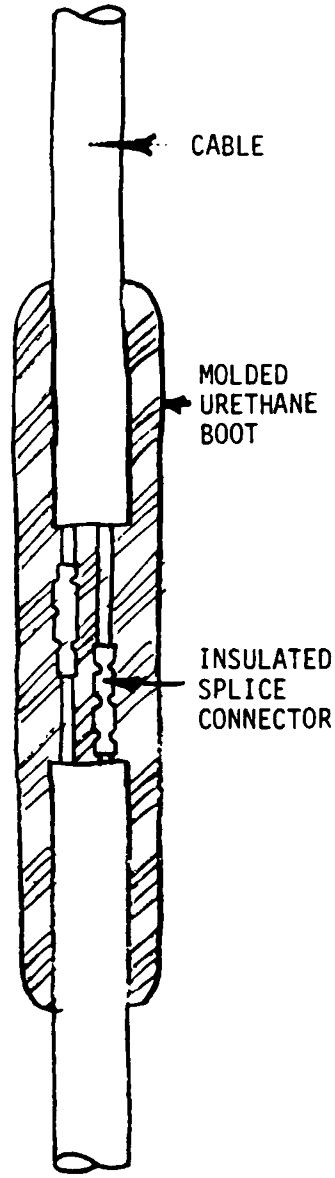
Figure 11-9 illustrates a typical machined metal or cast epoxy mold and a cross-sectional view of the finished splice. Figure 11-10 shows the expedient molding form made from heat-shrinkable tubing and the resultant cable splice.

11.8 (Continued)

This type of splice would be adequate for deep submergence application.



(A) URETHANE SPLICE
MOLD HALF



(B) SECTION THROUGH
COMPLETED SPLICE

FIGURE 11-9 POLYURETHANE RUBBER CABLE SPLICE FABRICATED FROM A SPLIT MOLD

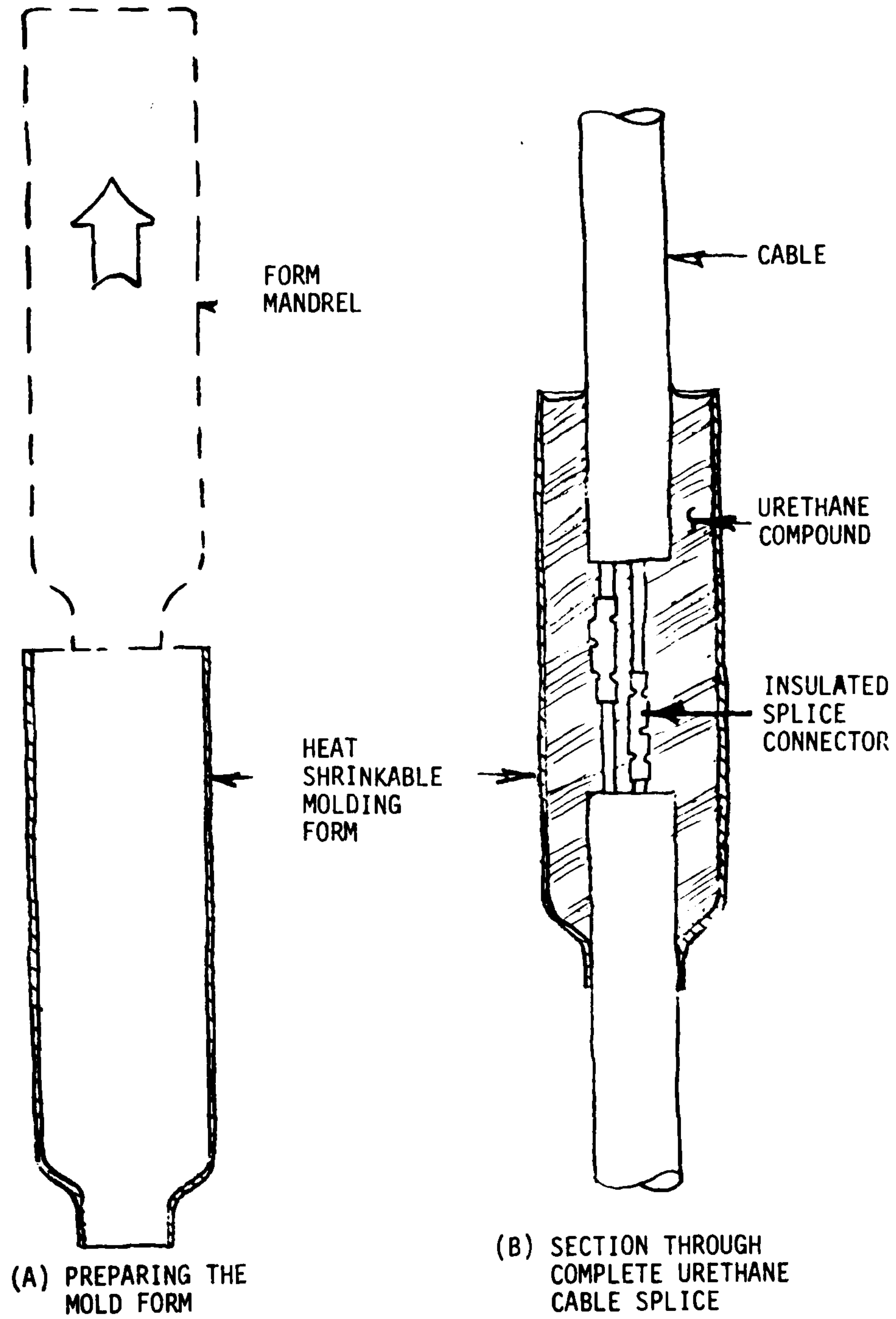


FIGURE 11-9 POLYURETHANE RUBBER CABLE SPLICE FABRICATED FROM SHRINK TUBING

11.9 Polyethylene Splice

The most common method of splicing polyethylene-jacketed cables is accomplished by the molded polyethylene method since other materials will not readily bond to it. The process involves the melting of polyethylene stock in a reservoir and injecting it from the reservoir under low pressure into the splice mold. The temperature at which the polyethylene is injected into the mold is critical; it should be sufficient to flow the plastic and also melt the parent insulation on the electrical cable in order to promote a complete fusion of the material. The correct temperature to which the polyethylene in the reservoir must be heated is governed primarily by the mechanics of heat transfer. This is influenced by the mold material, the mass of the mold, cavity volume, cavity shape, cable insulation thickness, insulation melting index, and conductor size. The melting index of cable insulation material and the stock introduced into the mold should be as high as practicable and as nearly alike as is possible. A high melting index is an indicator of high material density, a requirement to resist stress cracking. All the other variables mentioned affect the injection temperature, this can be modified by mold preheating to reduce thermal losses.

A disadvantage of the polyethylene molding system is that it requires a degree of skill by the operator and specialized tooling.

11.9 (Continued)

The mold used in this operation is usually constructed from stress-relieved, clear acrylic plastic which allows the operator a view at all times of the injection sequence. This aids in eliminating entrained air and reduces the probability of a "cold joint" occurring. It is virtually impossible, however, to determine whether a "cold joint" exists once the material has solidified. The location of the splice connections can also be viewed during the polyethylene injection process.

Figure 11-11 shows a typical mold used in the polyethylene molding system. The mold cavity must be shaped to avoid depositing molten polyethylene in thin sections since these have insufficient heat content to fuse the adjacent, thicker jacket material. Premature curing will result at the thin section, and separation will occur. Figure 11-12 shows a molded polyethylene splice.

The polyethylene system has been used primarily in Europe and, in particular, in British marine applications. It has gained popularity there due to its availability, low cost, and excellent electrical characteristics. It must be used as a splicing method when using polyethylene cable since no alternative it available. Furthermore, it is capable of providing reliable service, but personnel experience and skill are required for its proper use. Specialized equipment and tooling are required to support the effort. Careful inspection by individuals skilled in the polyethylene molding process must also be maintained.

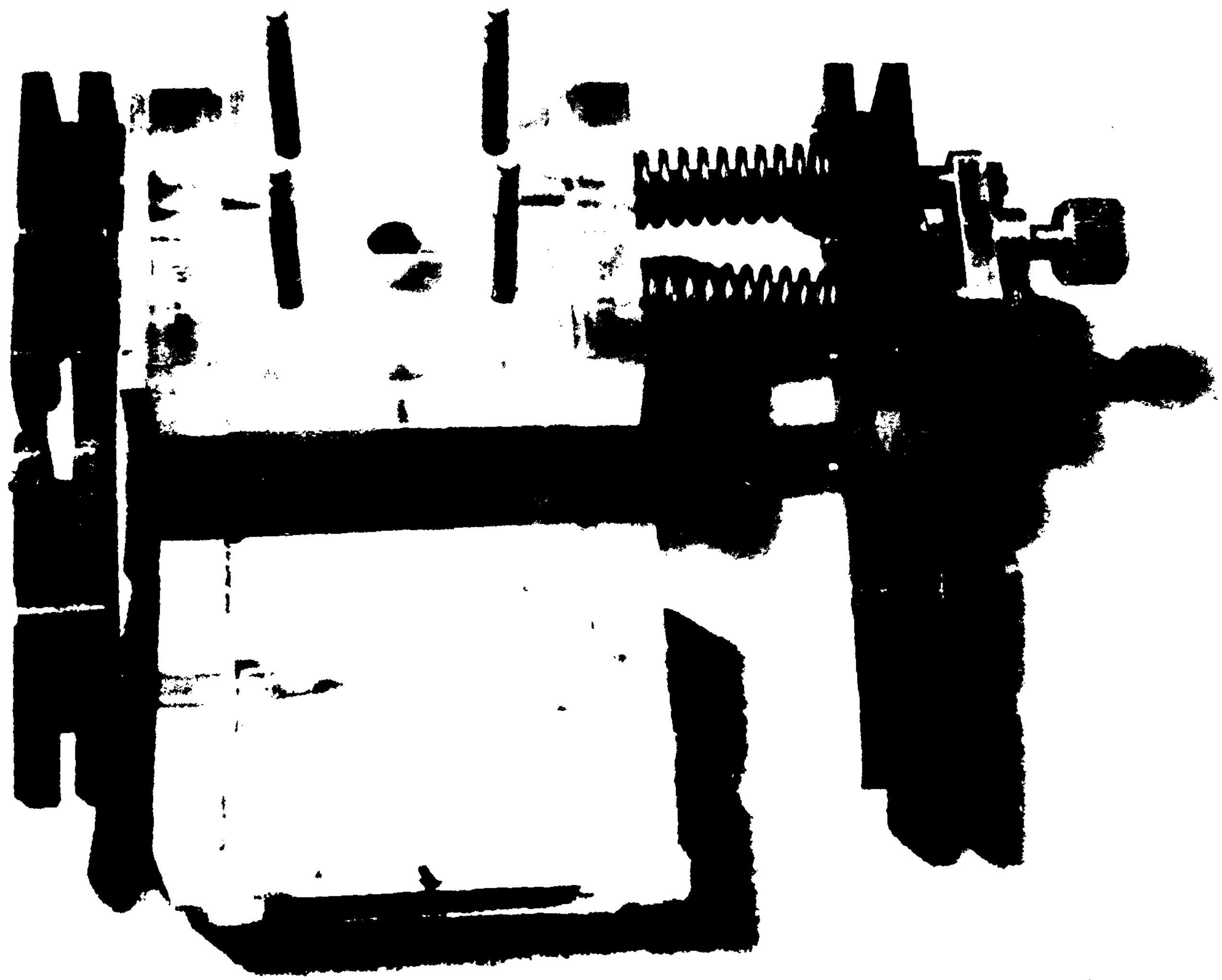
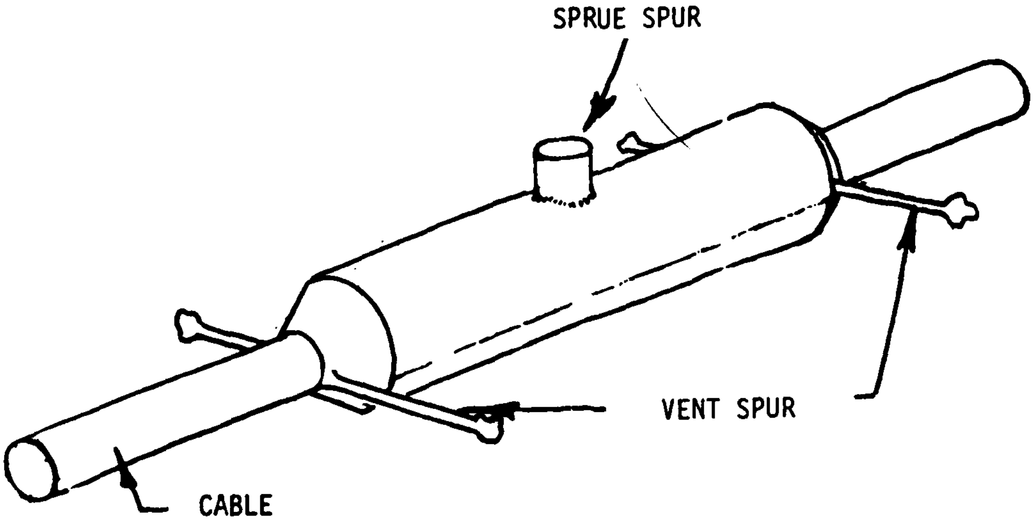
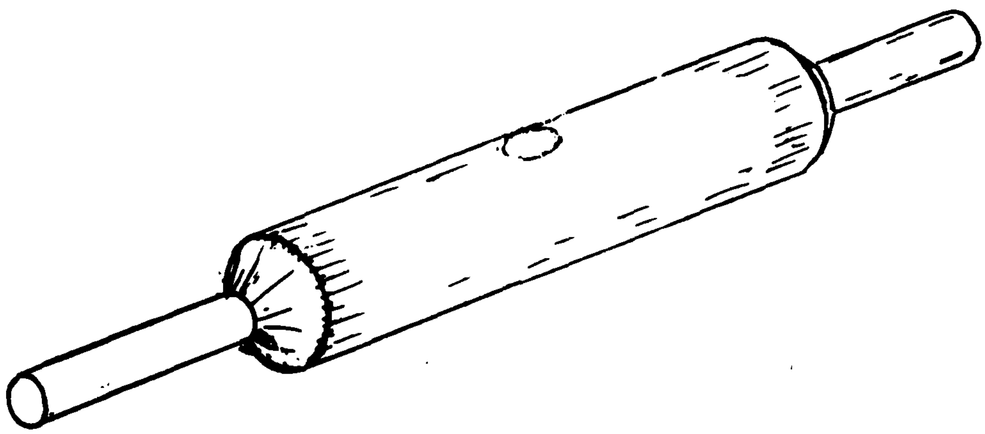


FIGURE 11-11 MOLD FOR A POLYETHYLENE SPLICE



(A) POLYETHYLENE SPLICE AS MOLDED



(B) TRIMMED POLYETHYLENE SPLICE

FIGURE 11-12 POLYETHYLENE SPLICE

11.10 Copper Tubing-Molded Rubber Splice

The Naval Research Laboratory, Orlando, Florida, has developed a molded rubber splice which utilizes a soft copper tubing to provide a termination to the braided shield of the cable.

As seen in Figure 11-13, the conductors are crimp terminated in the normal manner and insulated with shrink tubing. The braided shields of both ends of the cable are placed over the cable jacket at the ends of the cable. A soft copper tubing is then slipped over the splice junction to cover the shield wires. The tubing is then swaged on to the cable ends as shown in Figure 11-13. The inside of the copper tubing containing the conductors is injected with hard cure epoxy. The tubing also provides mechanical protection as well as terminating the cable shield. The final splice operation requires molding a rubber boot over the primed cable jacket and copper tubing. Polyurethane or neoprene rubber can be used.

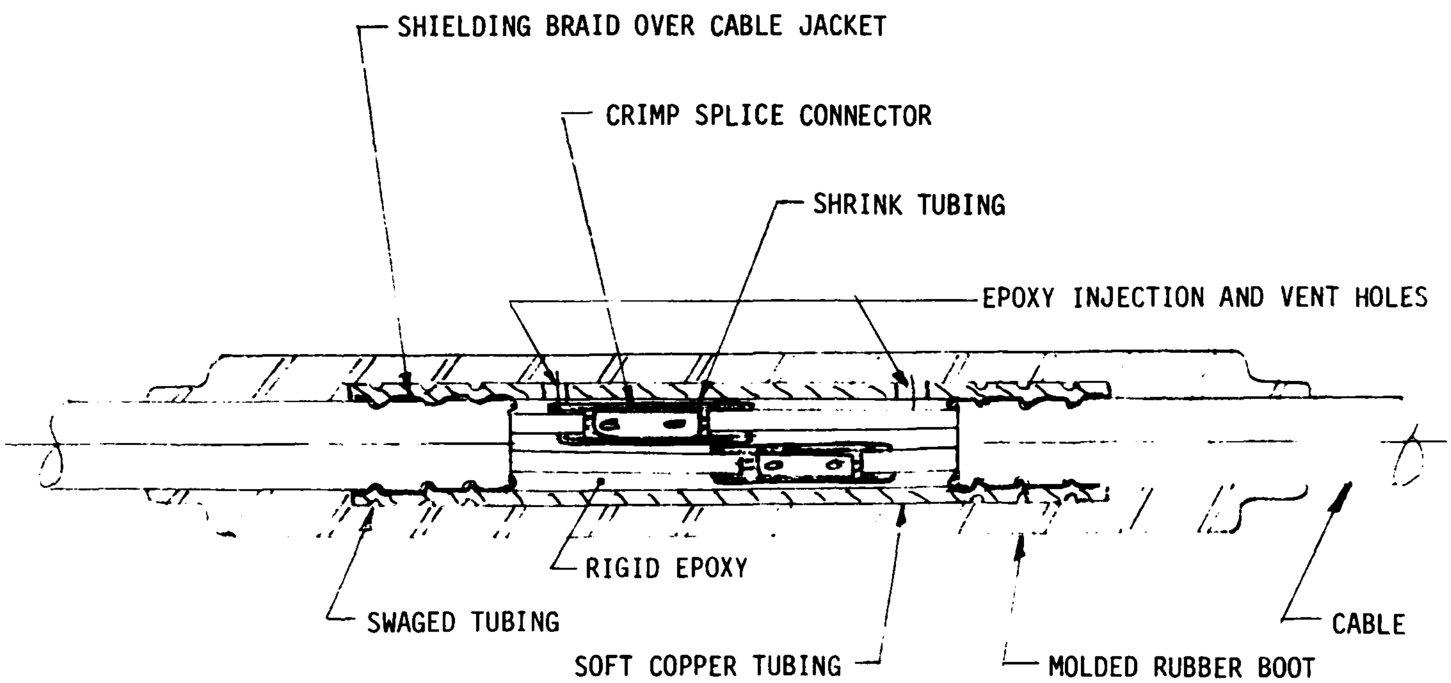


FIGURE 11-13 COPPER TUBING - MOLDED RUBBER SPLICE

11.11 Cable Splicing Equipment Manufacturers

A large number of manufacturers supply cable splicing equipment and materials. Some of these manufacturers and their product lines are noted in the following paragraphs.

11.11.1 Tape Splice Manufacturers

The following companies provide tape products for splicing.

	Tape Type
Bishop Electric A Unit of General Signal 10 Canfield Road Cedar Grove, NJ 07009	Bishop No. 44 Bi-Prene Type C Electrical Jacketing Tape
The Okonite Company Ramsey, NJ 07446	Okonite Vulcanizer Tape
AMP Special Industries Division of AMP Products Corp. Valley Forge, PA 19482	AMPLISEAL Heat-Shrinkable Self-Sealing Tape
3M Company Electro-Products Division 225-4N 3M Center St. Paul, MI 55101	Scotch 88 Vinyl Plastic Electrical Tape

11.11.2 Epoxy Splice Kit Manufacturers

The epoxy splice kit approved by the Navy on NAVSEA Drawing 815-1197255 is splicing kit no. 82-A1 with resin no. 4 epoxy as manufactured by the 3M Company, Electro-Products Division, St. Paul, MI.

11.11.3 Polyurethane Rubber Splice Kit Manufacturers

A polyurethane rubber cable splicing kit is available from the Hexcel Corporation, Rezolin Division, 20701 Nordhoff Street, Chatsworth, CA 91311. The splicing kit number is 9650. It contains a two piece snap on mold, and a 185N polyurethane rubber encapsulant. The kit is available in 4 sizes to suit different diameter cables as follows:

	Cable Diameter	Mold Dimensions
Size A	to 1/2"	7" x 1" diameter
Size B	1/2 to 3/4"	10-5/8" x 1-1/4" diameter
Size C	3/4 to 1-1/2"	15" x 1-3/4" diameter
Size D	1/2 to 2-1/4"	21-1/2" x 2-3/4" diameter

A polyurethane splice kit is also available from the Zippertubing Company, P.O. Box 61248, Los Angeles, CA 90061. The splicing kit number is P-171-1-MESA. The entire kit consists of a zipper jacket, a foam filler material, polyurethane cartridges, a cartridge dispenser, and a cable jacket cleaner. A kit is available for 1/2 inch and smaller diameter cables and 5/8 inch to 1 inch diameter cables. "Sea Splice" is the trade name for the cable splice assembly offered by the Zippertubing Company.

11.11.4 Neoprene Rubber Splice Kit Manufacturers

The following manufacturers are known to supply equipment to prepare neoprene rubber splices:

Hotsplicer Systems
Reliable Electric Company
11333 Addison Street
Franklin Park, IL 60131

11.11.4 (Continued)

Joy Manufacturing Company
Electrical Products
338 South Broadway
New Philadelphia, OH 44663

11.11.5 Polyethylene Splice Kit Manufacturers

Polyethylene cable splicing kits are available from the following manufacturers:

1. Standard Telephone & Cables, Ltd.
   A British Company of ITT
   Hydrospace Division
   591 Camino de la Reina, Suite 1024
   San Diego, CA 92108

2. Harrel, Inc.
   16 Fitch Street
   East Norwalk, CT 06855

3. Hotsplicer Systems
   Reliance Electric Company
   11333 Addison Street
   Franklin Park, IL 60131

4. General Dynamics
   Electric Boat Division
   Groton, CT 06340
   Attn: R.F. Haworth

5. Raychem Corporation
   300 Constitution Drive
   Menlo Park, CA 94025

11.11.6 Heat Shrink Tubing Splice Kit Manufacturers

The following companies offer kits for fabricating watertight heat shrink tubing cable splices:

1. Raychem Corporation
   300 Constitution Drive
   Menlo Park, CA 94025

2. Amp Special Industries
   Division of Amp Products Division
   Valley Forge, PA 19482

11.11.7 Pre-Stretched Tubing Splice Kit Manufacturers

The 3M Company, St. Paul, MI, supplies a kit which includes a splicing kit with a pre-stretched ethylene propylene tubular splice assembled onto a removable collapsable core.

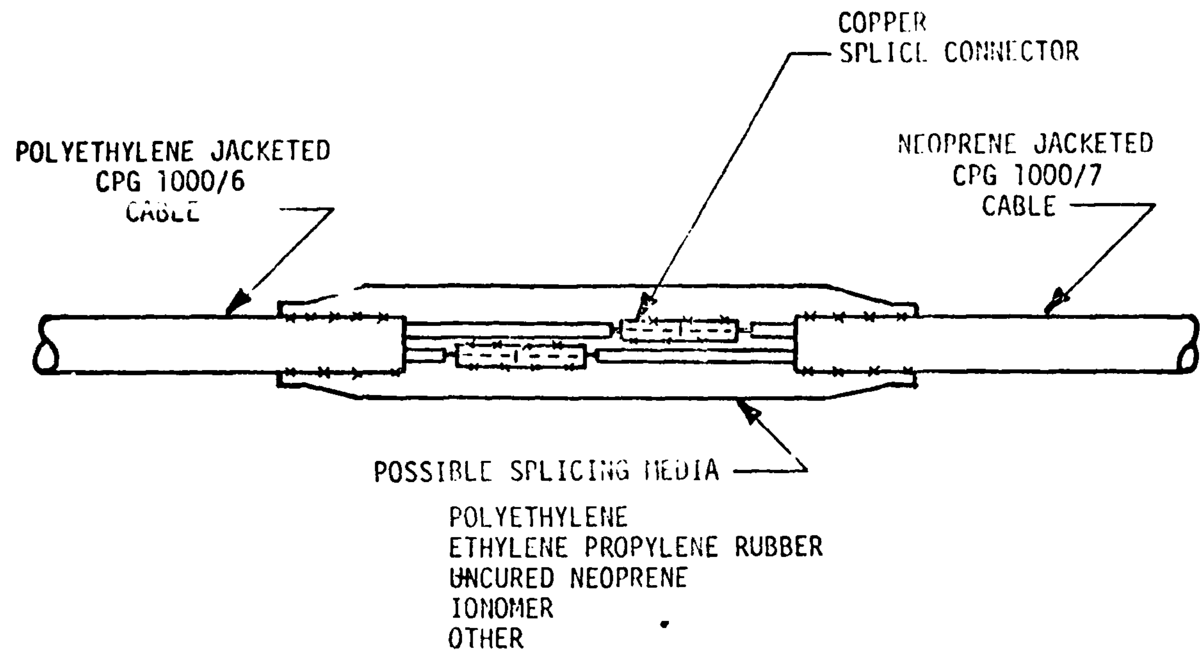
11.12 Polyethylene Splice for Joining Neoprene to Polyethylene Jacketed Cables

11.12.1 Introduction/Summary

Under the TRIDENT submarine development program, Electric Boat Division conducted basic studies in bonding polyethylene to neoprene and copper metal. (Reference 11-9). The objective of these studies were to identify techniques for splicing 1PR-A20E type polyethylene to DSS-3 type neoprene jacketed cables utilizing polyethylene as a splicing medium and to simultaneously attain a water dam at the copper connectors joining the conductors within the cable splice in the event submerged cables were severed. The bonding problems posed are shown in Figure 11-14.

The principal findings of the basic studies were as follows:

1. To attain a satisfactory bond of molten polyethylene to cured neoprene, the rubber must be coated with an adhesive system. Use of Thixon 1654 (Dayton Chemical), followed by an adhesive top coat (Table 11-1), produced bonds resulting in cohesive failure of the neoprene and a bond resistant to sea water when statically stressed. The adhesive system must be heat cured (300-350°F) for about 30 minutes.
2. Molten polyethylene exhibits some adhesion to clean, abraded copper surfaces. However, to attain a good polyethylene to copper metal bond resistant to sea water while statically stressed, an adhesive system is also required. Application of FM-47 vinyl-phenolic primer (American Cyanamid), followed by an Surlyn 1650 Ionomer top coat (DuPont) to the copper surface, produces water resistant bonds.



CROSS HATCHED LINES INDICATE BONDING INTERFACES OF INTEREST

FIGURE 11-14 POLYETHYLENE CABLE SPLICE

TABLE 11-1

EB Adhesive Topcoat*

1. Add 25 parts by weight of Philips #50406 hydrogenated polybutadiene to 75 parts by weight of uncured neoprene meeting EBSpec. 2580. (See Formulation below).

2. Blend on a cold Allen Bradley mill for 5 - 10 minutes.

3. Dissolve 10 gms of above mixture in 100 ml of trichloroethylene.

4. With thorough mixing, add 0.5 gm of dicumyl peroxide (Lucidol 500R), 1 gm of carbon black (Cabot - Monarch 1100) and 0.5 gm of zinc oxide.

5. Thoroughly mix adhesive before using.

* Not Optimized.

11.12.1 (Continued)

3. Cables containing Tefzel insulated conductors are more easily spliced than cables containing polypropylene insulated conductors because of greater temperature tolerance.

4. Mold temperature is more critical than extruder temperature in obtaining good splices.

11.12.2 EB Division Experimental Equipment for Splicing Polyethylene Neoprene Jacketed Cables with Polyethylene

The apparatus constructed for molding splices with polyethylene is shown in Figure 11-15. Components identified by numbers in Figure 2 are as follows: (1) air cooling control valve, (2) mold temperature monitor, (3) extruder temperature control, (4) mold mounted for injection, and (5) extruder. The mold used for producing splices, cables prepared for splicing and slugs of polyethylene used for producing splices are shown in Figure 11-16.

11.12.3 Procedure for Splicing Polyethylene and Neoprene Jacketed Cables with Polyethylene

Although splicing procedure development was terminated before optimal molding details were resolved, it is believed that water resistant polyethylene/neoprene cable splices waterblocked can be made by the following procedure:

1. Abrade copper crimp connectors with 80 mesh aluminum oxide abrasive paper. Mount crimp connectors on wooden sticks (cotton swab application stick).

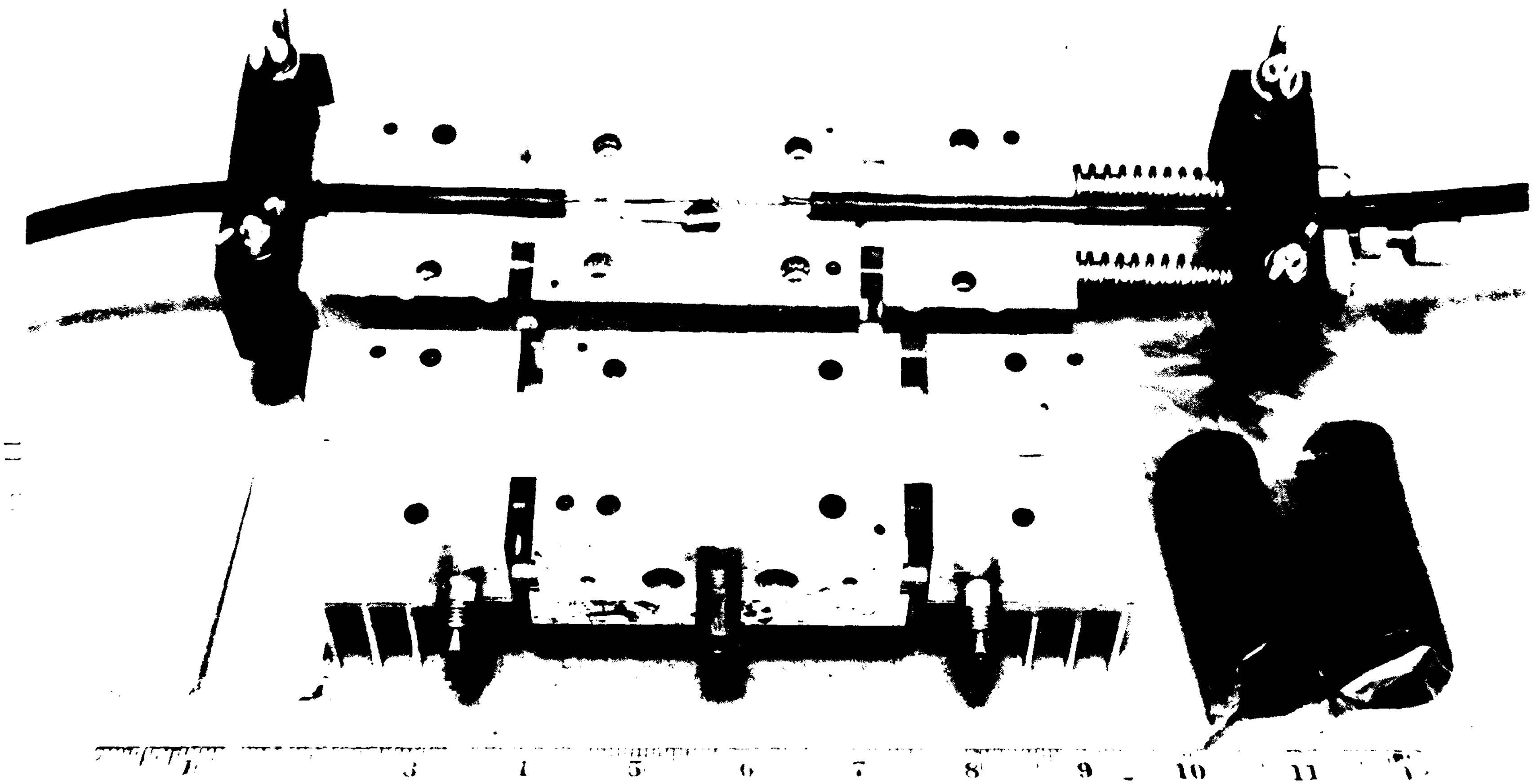
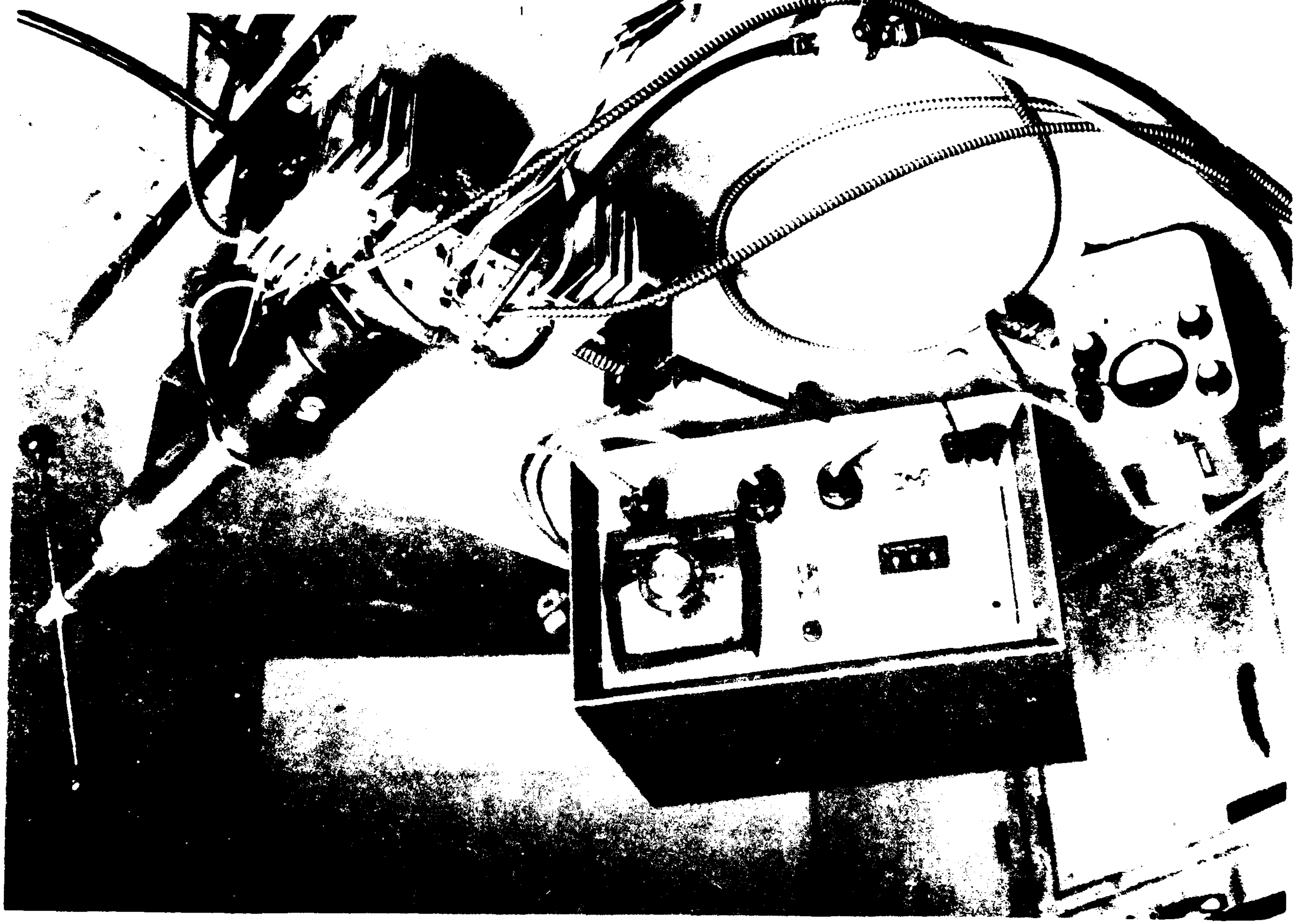


FIGURE 11-15

Splice Mold With Cables
Positioned for Molding



11.12.3 (Continued)

2. Wash copper crimp connectors with MEK. Air dry.

3. Brush apply one coat of FM-47 (American Cyanamid) - diluted to 5% by weight solids with FM-47 thinner (American Cyanamid). Air dry.

4. Heat FM-47 coated crimp connectors to 400°F in an oven.

5. Dip hot connectors into a container of Surlyn 1650 (DuPont) powder to obtain a thin coating of Surlyn 1650.

6. Allow copper connectors coated with FM-47 and Surlyn 1650 to cool to room temperature.

7. Cut cable and prepare conductor joints using coated crimp connectors, according to the sketch given in Figure 11-14.

8. Abrade bonding surface of neoprene cable jacket with #80 aluminum oxide abrasive paper. Wash abraded area with methyl ethyl ketone. Air dry.

9. Brush apply 1 coat of Thixon 1654 to neoprene cable jacket. Air dry.

10. Brush apply 1 coat of EB top coat (Table 11-1) to neoprene cable jacket.

11. Wash the polyethylene cable jacket to be bonded with methyl ethyl ketone. Air dry.

12. Mount area to be spliced in splice mold and attach to extruder.

13. Set mold and extruder temperatures at 300-350°F and 400-450°F, respectively.

14. When mold attains a temperature of 300-350°F, inject polyethylene. Force polyethylene into the mold by screwing the injection ram until flow is observed out of the sprue ports then turn extruder heaters off.

11.12.3 (Continued)

15. Hold mold at temperature for 15 to 30 minutes maintaining pressure to permit cure of adhesive systems. Keep light pressure on ram until sprue runners become translucent.

16. Allow mold to cool to 100°F before disassembling.

17. Trim flashing and cut sprue runners.

REFERENCES

11-1 MIL-E-16366, "Electrical Clamps, Lug Terminals and Conductor Splices - Pressure Grip"

11-2 NAVSEA Drawing 803-5001027, "Electric Plant Installation Standard Methods"

11-3 NAVSHIPS Drawing 815-1197255, "Epoxy Splice Kit for DSS-3 Cable and Plug Assembly Repair"

11-4 Grice, F., "Conductor Splices", Oceanology International, July, 1971

11-5 Biddell, W., "Performance Qualification Testing of Thermofit Marine Cable Splices", Raychem Corporation, Laboratory Report No.: 1107, 8 April 1970

11-6 PST Connector Insulator - 3M Company, St. Paul, MI

11-7 Cameron, R.L & Sanford, H.L., "Design Study Report - Molded DSS-3 Cable Splices for External Use on Submarines", EBDivision Report No.: U 413-62-211, 12 December 1962

11-8 NAVSHIPS Drawing 815-1197343, "Watertight Splice for DSS-3 Cable-Wiring and Molding Procedures"

11-9 ZURAW, E. A. "Elements of Polyethylene-Neoprene Cabling Splicing" Electric Boat Division Report No. U440-74-134, 20 Dec 1974.

(Blank)

SECTION 12

CABLE HARNESS TEST REQUIREMENTS

LIST OF FIGURES

LIST OF TABLES

12.1 Introduction

Two series of tests are very important in the design and production of pressure-proof cable harnesses. They are:

(a) Qualification (preproduction)
(b) Quality conformance inspection (production)

12.2 Qualification Tests

The qualification tests verify the design adequacy and manufacturer's ability to fabricate the harnesses. These tests allow the fabricator to be placed on the Qualified Products List (QPL). A recommended test sequence is noted in Table 12-1.

TABLE 12-1

Qualification Sequence Testing of Harnesses

Test Title	Paragraph	Control Test
Examination of Product	12.4.1	-
Continuity	12.4.2	-
Insulation Resistance	12.4.3	-
Dielectric Withstanding Voltage	12.4.4	-
Cable Flexing	12.4.5	12.4.2 12.4.3
Hydrostatic Pressure-Static	12.4.6	12.4.2 12.4.3 12.4.4

TABLE 12-1

(Cont'd)

Test Title	Paragraph	Control Test
Thermal Shock	12.4.7	12.4.2
Vibration	12.4.8	12.4.2 12.4.3
Shock	12.4.9	12.4.2 12.4.3
Accelerated Aging	12.4.10	12.4.2 12.4.3
Hydrostatic Pressure-Cycling	12.4.11	12.4.2 12.4.3
Bonding-Destructive	12.4.12	-
Post-Test Examination of Product	12.4.13	-

12.3 Quality Conformance Tests

The quality conformance tests are conducted to assure the buyer of the quality of each harness purchased. These tests are conducted on each completed harness prior to shipment to the customer. A recommended test sequence is noted in Table 12-2.

TABLE 12-2

Quality Conformance Sequence Testing of Harnesses

Test Title	Paragraph	Control Test
Examination of Product	12.4.1	-
Continuity	12.4.2	-
Insulation Resistance	12.4.3	-
Dielectric Withstanding Voltage	12.4.4	-
Hydrostatic Pressure - Static	12.4.6	12.4.2 12.4.3
Dielectric Withstanding Voltage	12.4.4	-
Post-Test Examination of Product	12.4.13	-

12.4 Test Methods and Performance Requirements

The following test methods and performance requirements should be used to determine the adequacy of a pressure-proof harness assembly used on submarines.

12.4.1 Examination of Product - Harnesses should be examined to ensure conformance with the applicable harness drawing and component specifications which include the following:

(a) Applicable specification drawing
(b) Materials
(c) Design and construction
(d) Identification of product
(e) Workmanship

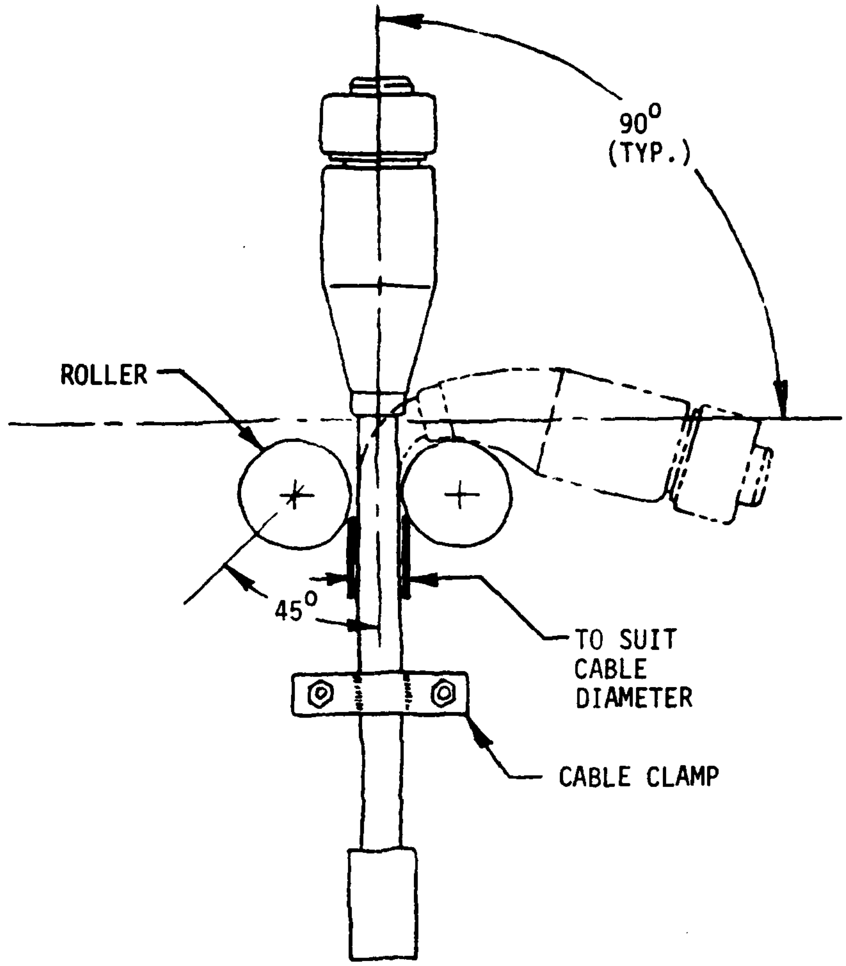


FIGURE 12-1 CABLE FLEXING TEST SETUP

12.4.2 Continuity - The wired harness assembly should be checked for continuity with a standard circuit tester. There should be no evidence of open circuits as a result of this test, and it should be verified that the conductors are connected in accordance with the wiring schematic of the applicable specification sheet.

12.4.3 Insulation Resistance - Harnesses should be insulation resistance tested in accordance with Method 3003 of MIL-STD-1344. The resistance should be measured between all contacts and between all contacts and including all contacts terminated to shields and the metal shell of the connector. When insulation resistance is measured during hydrostatic measure test (paras. 12.4.6 and 12.4.11) measurements should be made between all contacts and water ground. All insulation resistances shall be greater than 5000 megohms.

12.4.4 Dielectric Withstanding Voltage - Harnesses should be tested in accordance with Method 3001 of MIL-STD-1344. The applicable test voltage (1,000 volts for the size 20 and 16 contacts and 1,900 volts for the size 12, 8, 4, 0 and 0000 contacts) should be applied between all contacts and between all contacts and the metal shell of the connector. There should be no evidence of a breakdown or flashover. (NOTE: VOLTAGES STATED ARE TYPICAL AND MAY VARY WITH REQUIREMENTS OF END APPLICATIONS).

12.4.5 Cable Flexing - In this test, the wired and molded connectors on each end of the harness should be loosely inserted between a pair of rollers (Figure 12-1) and should be subjected to 90° bending in each direction at a rate of 12 to 14 complete cycles, 360° total travel, per minute. The bonded joint between the boot and the cable jacket should be located approximately 45° above the centerline through the two rolls. The lower end

12.4.5 (Continued)

of the specimen should be firmly clamped. The clamp should be designed to apply a uniform radial pressure to the core of the cable. The diameter of the rollers should be 2 inches for cables 3/4 inch in diameter, under 3 inches for 3/4 to 1-1/4 inch diameter cables, and 5 inches for 1-1/4 to 2 inch diameter cables. The cables should be rotated 90^{o} inside the clamp and the test should be repeated. A complete test of a connector assembly should consist of two cycling tests of 100 cycles each. The cable flexing test should be conducted on each end of the harness assembly. There should be no evidence of electrical defects (insulation resistance and continuity) or damage to the molded boot and boot seals as a result of this test.

12.4.6 Hydrostatic Pressure - Static - To conduct the static hydrostatic pressure test, the harness assembly should be mated to a receptacle mounted to the internal side of a pressure vessel. A pressure-proof plug or receptacle cover (as applicable) should be mated to the other end of the harness. The harness assembly should be tested in a pressure vessel filled with clean tap water. The harness should be tested to one and one-half times the maximum operating pressure of the harness assembly as shown in Table 12-3. There should be no evidence of water entry into the harness assembly as a result of the pressure test, nor a deterioration of electrical characteristics which were measured prior to the initiation of the test.

TABLE 12-3

Static Hydrostatic Pressure Test Schedule

Step	Pressure (psig)		Hold Time (minutes)
	Low	High	
1	0	100	5
2	0	100	5
3	0	100	5
4	0	1,000	5
5	0	*	24 Hours

* 1-1/2 times maximum operating pressure.

12.4.7 <u>Thermal Shock</u> - Harnesses should be subjected to the thermal shock tests specified in Method 1003 of MIL-STD-1344. The thermal shock test conditions noted in Table 12-4 should be used. No visual damage should be evident as a result of this test.

TABLE 12-4

Thermal Shock Test Conditions

Step	Temperature $^{\circ}$F
1	$-65^{\circ}\,{}^{+0}_{-9}$
2	$+68^{\circ} \pm 5$
3	$+165^{\circ}\,{}^{+9}_{-0}$
4	$+68^{\circ} \pm 5$

12.4.8 Vibration - Harnesses should be vibrated in accordance with MIL-STD-167, Type 1 classification. Connector leads shall be wired in series and should be connected with a suitable testing circuit. A voltage and current within the connector rating shall be applied throughout the vibration test. The mating plug coupling nut should be held in place by the normal locking device. Cables should be supported on a stationary frame not closer than 12 inches from the connectors. There should be no damage to the harness assembly and no loosening of parts as a result of this test. There should be no interruption of electrical continuity longer than 10 milliseconds.

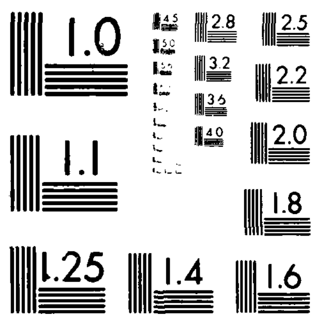
12.4.9 Shock - Harnesses should be tested in accordance with MIL-S-901, Grade A, Class 1, Type A. Three blows should be applied in each direction of the three major axes of the harness assembly, which is mounted on a shock device or carraige. The plug coupling nut shall be held in place by normal locking means. All contacts shall be wired in series, and the cables should be clamped to structures that move with the harness. The cable(s) shall be unsupported for a minimum distance of 12 inches from the plug. A suitable instrument shall be employed to indicate any discontinuity exceeding 10 milliseconds in the circuit. There should be no damage to the harness assembly and no loosening of parts as a result of this test. There should be no interruption of electrical continuity longer than 10 milliseconds.

12.4.10 Accelerated Aging - The harness assembly should be subjected to an accelerated aging test for a period of 1000 hours. The temperature should be 155° to 165°F with a relative humidity of 95 percent. Immediately before and after testing, the assembly should be subjected to an insulation resistance test. The connectors should be suitably sealed for this test.

AD-A111 931   GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV   F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81   R F HAWORTH   N61339-80-C-0021

UNCLASSIFIED   NRL-MR-4601   NL

7 OF 8
AD
A111931



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

12.4.10 (Continued)

Insulation resistance shall be greater than 100 megohms following this test, and the assembly should be capable of meeting the bond strength requirements of Section 12.4.12 (Reference 5-5).

12.4.11 Hydrostatic Pressure - Cycling - The harness assembly should be installed in a pressure vessel with both connectors mated to matching connectors mounted on the cover of the pressure vessel. The pressure vessel test medium shall be seawater per ASTM D-1141-52. The harness assembly shall be subjected to 2000 cycles of hydrostatic pressure equivalent to a ship operating depth. The test cycle shall be as follows: five minutes at 0 psig, 10 minutes to rise to the test depth pressure, 5 minutes held at test depth pressure, and 10 minutes to drop to 0 pressure. The time duration of each pressure cycle shall be 30 minutes $\pm$ 1 minute. Seawater temperature for the first 500 cycles shall be 32° to 36°F; the temperature for the next 1000 cycles shall be 40° to 84°F: and the last 500 cycles shall be conducted at a 140°F seawater temperature. All circuits shall be loaded at 1 ampere, 110 volts AC during the test. Insulation resistance readings shall be taken before, at the time of each seawater temperature change (500 and 1500 cycles), and following the completion of the test program. There should be no evidence of mechanical damage, water leakage, or impaired electrical characteristics as a result of this test.

12.4.12 Bond - Boot To Connector (Destructive) - The molded boots of the connectors on each end of the harness should be subjected to a boot-bond test as shown in Figure 12-2. The plug boot should be prepared as shown in the figure. The slit portion of the molded boot is to be pried back to obtain evidence of a properly bonded rubber-to-metal bond. Evidence of an improperly bonded area in excess of 2 percent should be cause for rejection (Reference 5-1).

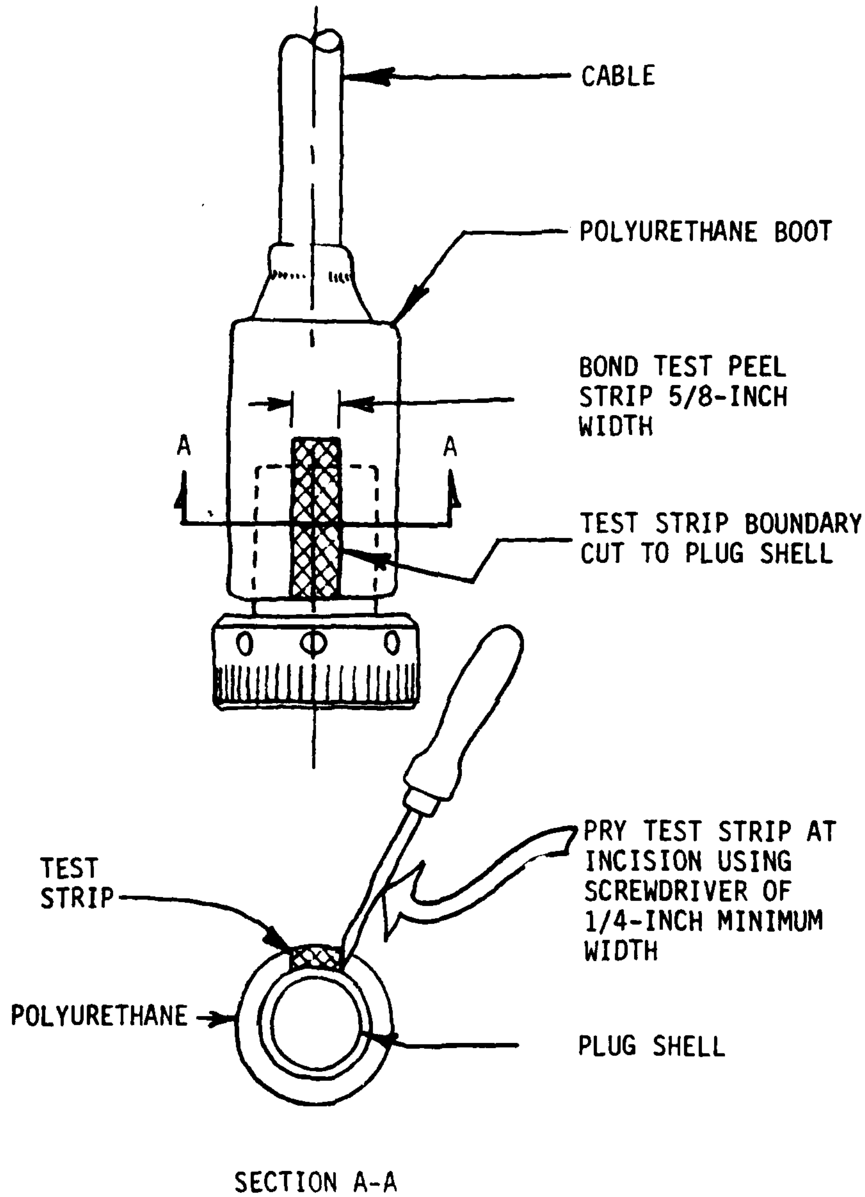


FIGURE 12-2. DESTRUCTIVE BOOT-TO-CONNECTOR BOND TEST

12.4.13 Post-Test Examination of Product - The harness assembly should be visually inspected for any physical changes resulting from the test.

12.4.14 Test for Strength of the Connector Boot-to-Connector Shell Bond

12.4.14.1 *Bond - Boot to Connector (Quantitative Destructive Evaluation)*

A destructive test has been recently developed at Electric Boat Division which provides for the quantitative evaluation of the molded boot bond to the connector backshell. The test specimens are prepared and tested as follows:

1. Cut away the cable end of the plug as shown in Figure 12-3.

2. Circumferentially cut the molded boot to the metal connector backshell according to Figure 12-3. The cutting process should yeild at least four (4) testable 1/4 inch wide specimens.

3. Make on longitudinal cut perpendicular to the circumferential cuts in line with the connector key.

4. Pry away each 1/4 inch wide specimen from the metal for a distance of 1/2 inch to provide a gripping tab for the peel tests.

5. Mount the connector on a fixture as shown in Figures 12-3 and 4. The fixture should permit rotation of the plug through 360 degrees while the test samples are pulled in peel.

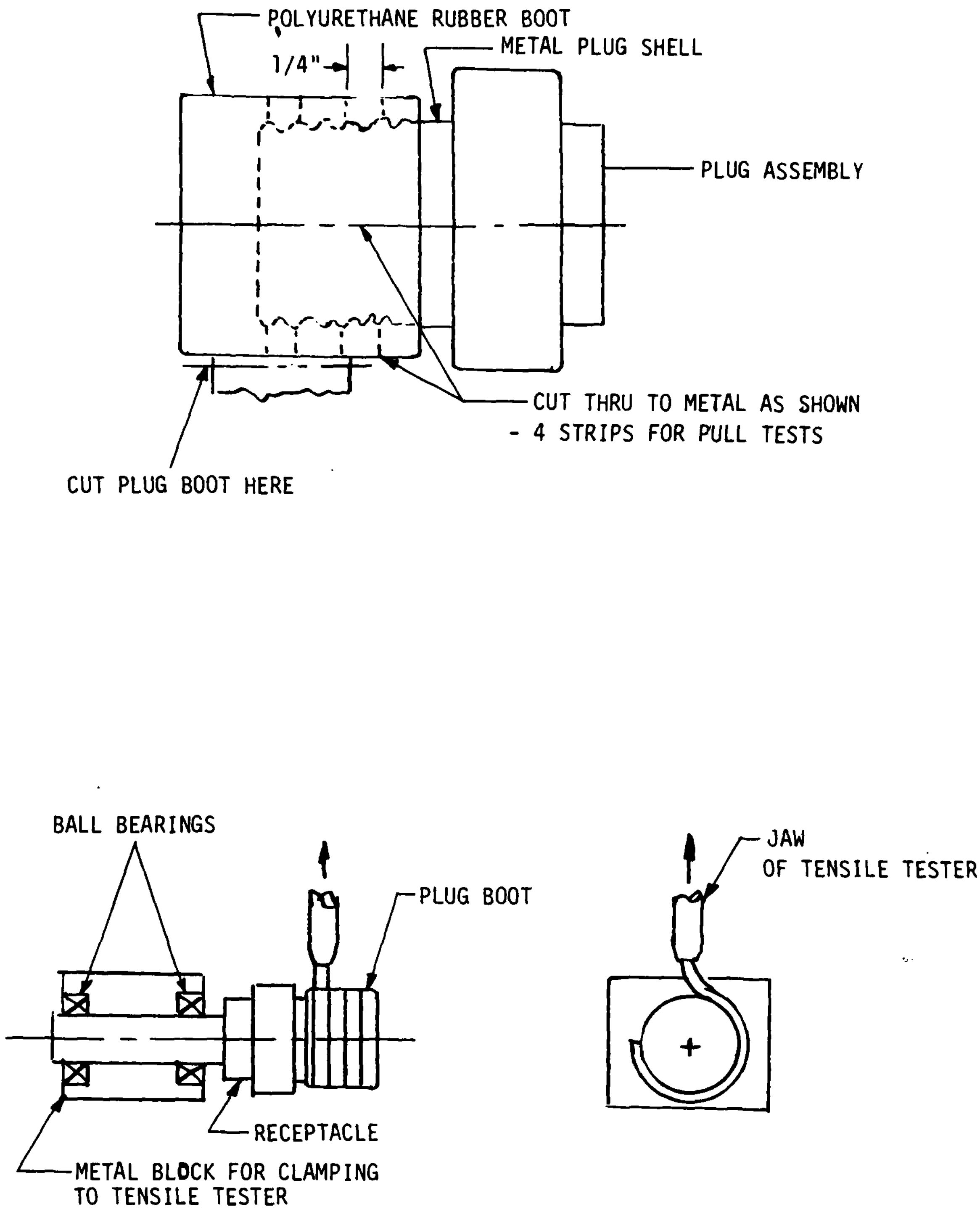


FIGURE 12-3 DESTRUCTIVE BOND TEST SET-UP PLUG BOOT-TO-SHELL

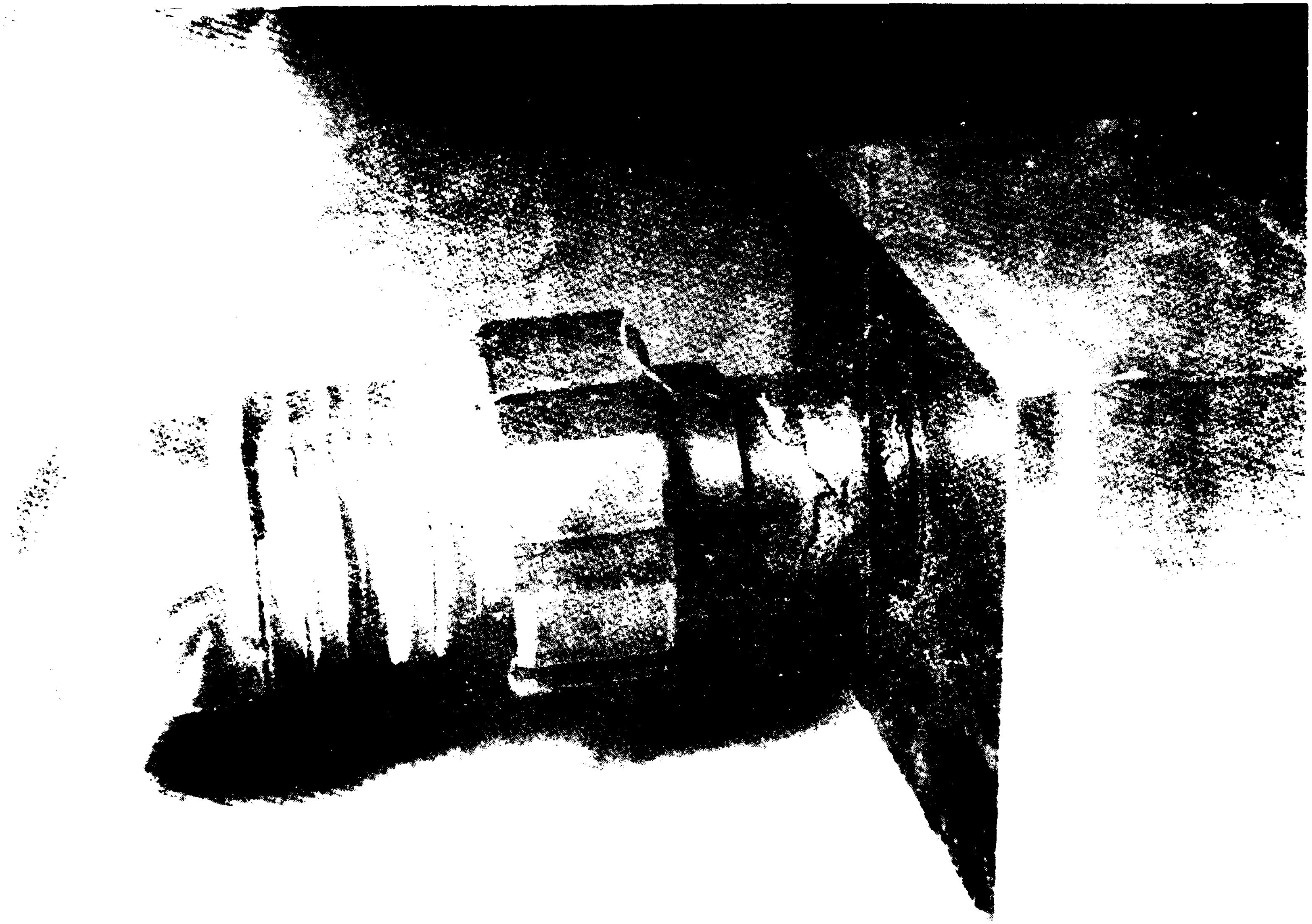


FIGURE 12-4 PLUG DESTRUCTIVE BEND TEST FIXTURE

12.4.14.1 (Continued)

6. Align and secure the fixture securely to the moving frame of the tensile test machine.

7. Clamp the tab of the test specimen to the stationary frame of the tensile test machine.

8. Pull the test specimens in 90^{o} peel at a rate of 2 inches per minute, and record the load required to peel the specimen free of shell. Note mode of failure. Test the four (4) specimens as noted above.

9. When tested as noted above, the boot-to-connector shell bond should exceed 40 pounds per inch. However, cohesive failure of the rubber is an indication of the desired bond condition.

12.4.15 <u>Test for Strength of Connector Boot to Cable Bond</u>

The bond of the connector boot to the cable jacket can be destructively tested as follows:

1. Cut axially four (4) 1/4" wide test specimens of the molded boot 90° apart as shown in Figure 12-5.

2. Cut the molded boot through to the cable jacket and past the end of the jacketed cable.

3. Pry away the boot of each 1/4" test specimen from the cable jacket for a distance of approximately 1/2" to provide a gripping tab for the peel tests.

4. Mount the cable in fixture with a Kellems Company cable grip as shown in Figure 12-5.

5. Align and clamp the fixture to the moving frame of the tensile test machine.

6. Clamp the tab of the first test specimen to the stationary frame of the tensile test machine.

7. Pull the test specimen in 90° peel at a rate of 2 inches per minute, and record the load required to peel the specimen. Note mode of failure. Test all four specimens as noted above.

8. The boot-to-cable bond shall result in cohesive failure of the rubber boot or cable jacket and not at the bonded interface.

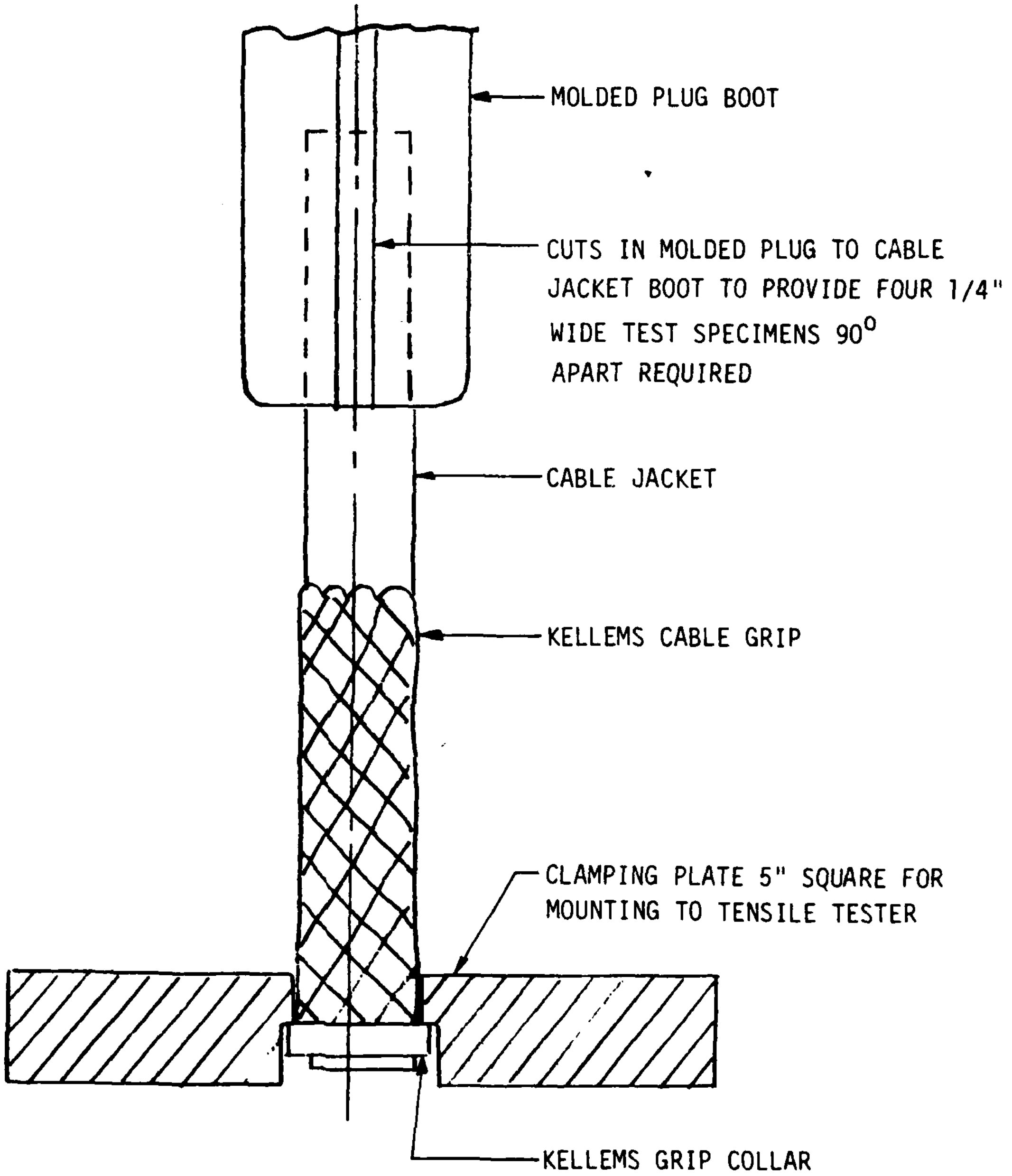


FIGURE 12-5 DESTRUCTIVE BOND TEST SET-UP - PLUG BOOT TO CABLE JACKET

(Blank)

SECTION 13

CABLE HARNESS HANDLING, INSTALLATION, REPLACEMENT, AND TESTING

LIST OF FIGURES

LIST OF TABLES

13.1 Introduction

This section specifies procedures for handling, installation, replacement, and testing of electrical/electronic components, and harnesses.

The information in prior sections of this Handbook is aimed at providing the best possible components for installation onboard submarines and surface ships. However, the information in this section has the greatest bearing on the reliability of this installation.

The fabrication, inspection, and test operations described in previous sections are performed in shop areas and therefore are relatively easy to accomplish with good quality control. In contrast, the operations described in this section must be performed onboard the ship, in most cases in crowded work areas.

These difficult working conditions must be overcome in two respects to ensure that onboard installations and repairs will be reliable. First, the work must be done in specific detail and with high quality regardless of personal discomfort. Second, the equipment must be adequately protected from damage caused by environmental factors during deployment and subsequent maintenance.

13.2 Cable Support and Protection Device Installation

All outboard electrical cables must be fully protected and supported. These cables are protected and supported with cable pans and angle bar. The cables must be protected as they have a jacket susceptible to damage in service and at installation. The cables are run in areas where they can be easily damaged by weld flash, sharp protrusions, and personnel stepping or dropping objects on them. The area is so congested that personnel must walk on existing foundations, equipment or other appendages. Therefore, all outboard equipment must be rugged to withstand the weight of tools and personnel working in these areas. The cables must also be protected and supported to withstand the hydrodynamic forces, to jacket wear and erosion by rubbing against foundations or other similar appendages, or from flotsam.

Adhere to the following installation and inspection criteria for the cable support devices.

1. The cable pans and angle bars must be fabricated in accordance with NAVSHIPS Drawing 815-1197446 (EBDivision Drawing EB-100789).

2. Once installed, the cable protection device must be clean and free of weld flash, dirt or other foreign matter that may puncture the cable jacket when clamping the cable to the pan or angle bar.

3. The cable pan or angle bar must be free of sharp edges.

4. Rubber channel must be provided where the cable exits or enters the pan, and around all cables inside the flexible couplings.

13.2 (Continued)

5. Cables must be firmly secured to the support devices with plastic straps.

6. A cable running to a retractable component cannot be a fixed installation. Such cables should be protected against abrasion and entanglement in a fiberglass guide.

7. The banding straps holding the cables to the pans or angles need only be snugly tightened over the cables. This will avoid damaging the cable jacket.

13.3 Cable Harness Handling

Due to the nature of outboard cable harness construction, the following general handling requirements must be observed:

1. Never bend cable tighter than its minimum bend radius.

2. When removing cable from a reel, or coiling or uncoiling pre-cut lengths, take extreme care not to kink or twist the cable. Always unroll cable from a reel or coil, since looping it off sides causes kinks.

3. Never use mechanical means, such as a rope or chain falls, to pull cable taut.

4. Ensure that cables are protected from mechanical damage at all times, especially in areas where personnel would be likely to step on or otherwise damage the cable.

13.4 Harness Installation

1. Carry the pretested cable harness to the submarine in a plastic bag to ensure protection in handling.

2. Begin the installation at the electrical hull penetrator.

3. Remove the receptacle protective cap in the hull penetrator receptacle and visually inspect the receptacle internals, O-ring and seal surface for cleanliness, lubricant and nicks or scratches.

4. Remove the non-ferrous metal protective cap on the hull penetrator plug end and visually inspect the gasket, and seal surfaces for cleanliness, lubricant and nicks and scratches on the seal surface.

5. Mate the plug assembly by hand to the receptacle. Complete the operation with a spanner wrench. <u>The plug must be taken up metal-to-metal with the receptacle.</u> This can be determined by LIGHTLY tapping the spanner handle with a metal rod. When the coupling nut is adequately tightened, the sound of the tapping will rise sharply in pitch to a "ping" sound. For spanner wrench required, see Table 13-1.

6. Run the cable into the existing protective devices. Clamp the cables to the matched angle bar with the plastic strap provided. The cables need not be clamped in the pans, however, until all the cables have been run in the trough. After clamping the cable, flex the unsupported parts of the cable loop to be sure that they will not be forced by

water turbulence into contact with surrounding structure. Observe minimum bend radius requirements.

7. Remove the non-ferrous metal protective cap on the equipment receptacle and visually inspect as described in Step 3 for the hull penetrator.

8. Remove the non-ferrous metal protective cap on the equipment plug end and visually inspect the plug as described in Step 4 for the hull penetrator end plug.

9. Mate the plug assembly by hand to its mating receptacle on the equipment. Complete the mating procedure as described in Step 5 for the hull penetrator.

10. When all the cables for a particular hull penetrator are mated to their respective receptacles, the cables can be banded to the support device at the hull penetrator. Use the straps to complete this operation.

11. Band the cables and pan covers to each pan after all cables in that pan have been installed.

12. When installing a harness which has been stored for an extended period, megger * the harness and check it for continuity before bringing the cable to the ship. Compare these readings with the measurements made on the harness after fabrication for evaluation of the harness's acceptability.

* Check insulation-resistance with megohmmeter.

13.5 Inspection, Handling, and Stocking O-Rings

13.5.1 General - O-rings should be handled with care like all gaskets. They should be kept packaged until ready for inspection and assembly to prevent damage. All "MIL-SPEC" O-rings are delivered with date of manufacture stamped on the package. All O-rings associated with connectors discussed in this manual are static applications.

O-rings should be installed or removed with a plastic O-ring tool. See Figure 13-1. Do not use knives, picks and other sharp objects as they may damage the O-ring groove surface as well as the O-ring.

In outboard electrical/electronic systems, O-rings seal plugs to receptacles. In MIL-C-24217 electrical connectors, a radial O-ring gasket is in the receptacle and a flat dovetail-grooved O-ring is in the plug. See Figure 13-2.

O-rings are provided with these connectors when purchased. Connector O-rings should not be installed until ready for service. The plug O-ring is installed following the plug wiring and molding just prior to pressure testing. The O-rings need not be replaced following the tests. Barring damage, the O-ring should see long service in this application. The O-rings should be lubricated with a thin coating of DC-55M or Cosmolube 615 lubricant prior to installation. The O-ring grooves must be free of dirt and other foreign particles to obtain the desired seal. The O-ring must be visually examined before installation to be sure it is free of nicks, dents or flats that would impair sealing. See MIL-STD-413, "Visual Inspection Guide For Rubber O-Rings", to determine the adequacy of the

13.5.1 (Continued)

O-rings for installation. Following many years of service the O-ring may take on a permanent set and flatten out in the seal area. At this time the O-ring should be replaced.

All connector O-rings should be replaced every five years or at a major overhaul, whichever comes first.

Whenever an installed outboard electrical connector is disconnected for any reason, the connector should be cleaned and the O-rings in the receptacle and plug replaced prior to reassembly. During initial "fit-up" and installation of new or replacement cable harness assemblies, if connectors must be disconnected, new O-rings need not be replaced. However, they should be inspected to ensure an undamaged condition.

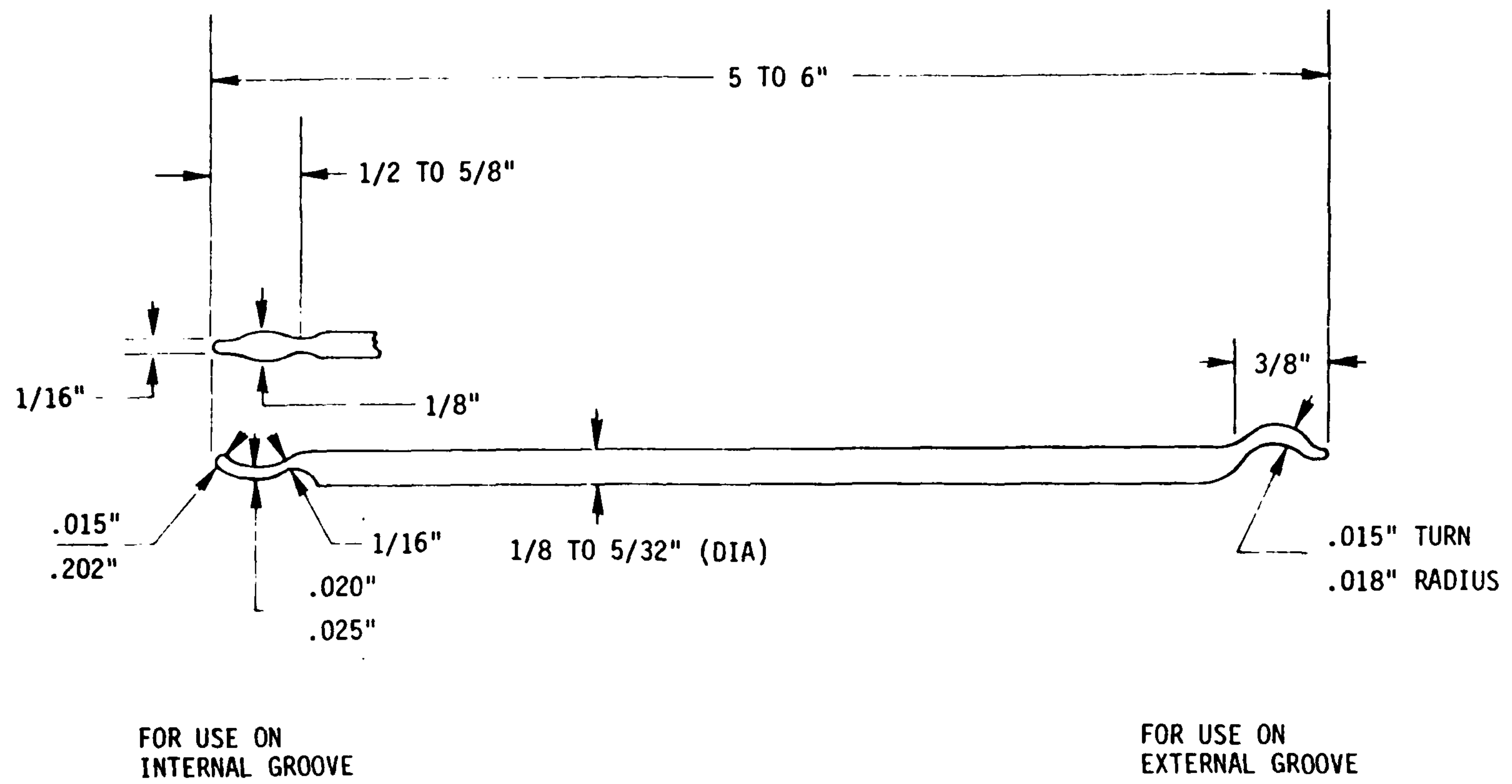


FIGURE 13-1 O-RING REMOVAL TOOL

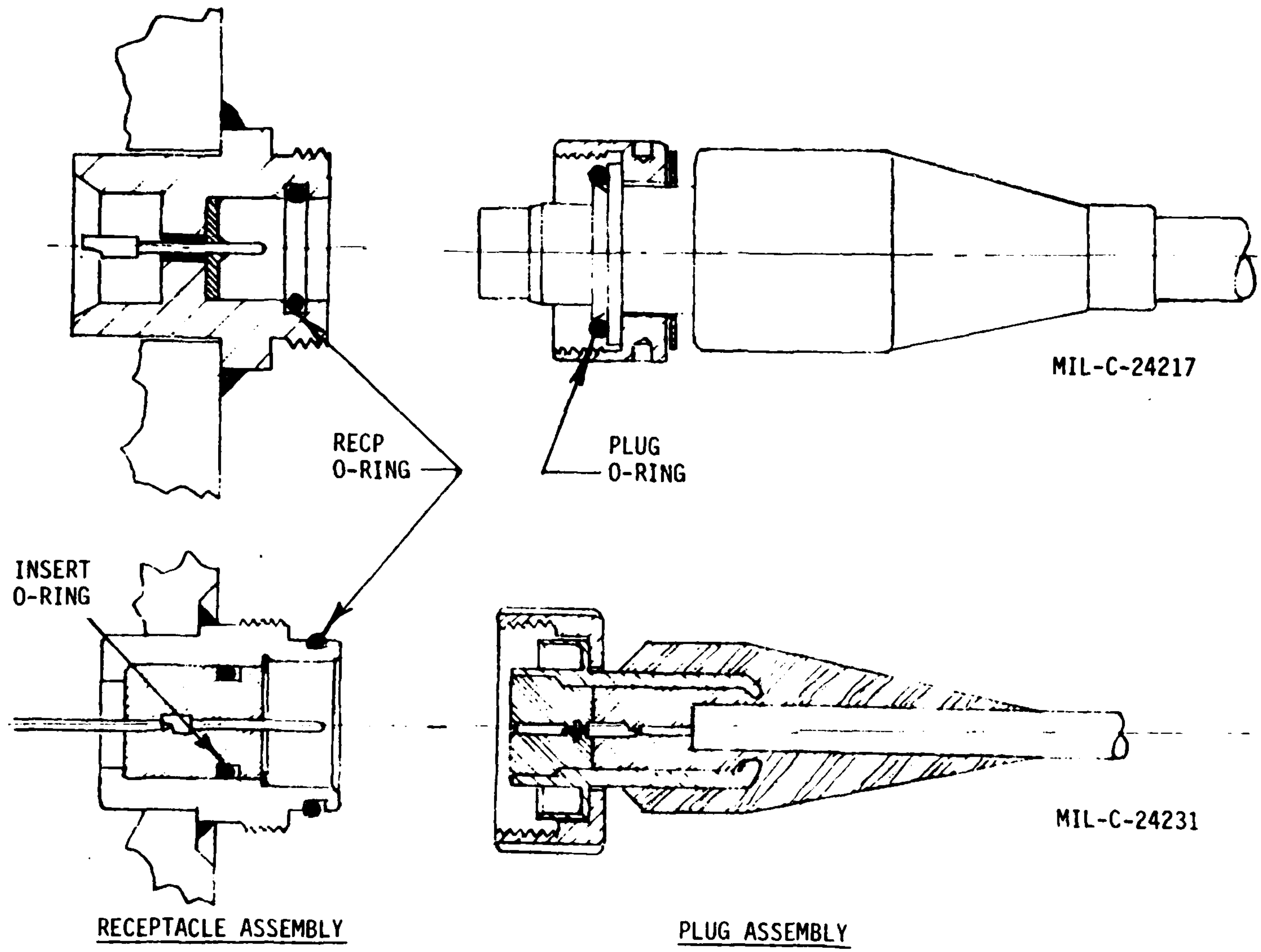


FIGURE 13-2 PLUG AND RECEPTACLE ASSEMBLY O-RING LOCATIONS

13.5.2 Stocking and Ordering O-Rings

When replacing an O-ring, the O-ring drawn from stock should be carefully handled and visually inspected for defects. MIL-STD-413 aptly shows the major defects that can be expected in O-ring manufacture, and must be referred to when inspecting O-rings. MIL-STD-177, "Terms for Visible Defects of Rubber Products", can be of service when reporting defects in the manufacturer's products.

Basically, the O-ring should be sized in accordance with the specifications, free of excessive flash, back rind, dents, depressions, flow lines, bad filling which cause dents and depressions, foreign materials and splits. To be recognized and appreciated, these defects must be viewed in MIL-STD-413. BUNA-N O-rings are packaged in dated containers. Do not use O-rings with a cure date in excess of twenty (20) calendar quarters. See MIL-HDBK-695,"Rubber Products: Recommended Shelf Life" for shelf life of other O-ring materials that may find use in these applications.

Correct identification of an O-ring must include its dimensions and material. The size is specified by the designation of a standard ARMY-NAVY (AN) or Military Standard (MS) drawing number. These drawings show the dimensions to which each O-ring size must conform. For the watertight connectors used on submarines, AN 6227, AN6230, or AS568 drawings are used where possible. O-rings of these sizes are stocked in shipyard and Navy installations.

The O-ring material specified in these applications in a BUNA-N compound which conforms to MIL-P-5516, Class B or MIL-P-25732. The BUNA-N material provides satisfactory service in a salt-water environment. For qualified suppliers see QUALIFIED PRODUCTS LISTING QPL-5516.

TABLE 13-1

Plug Coupling Ring Tool List

Plug Size		Adjustable Spanner Wrench (Size & Type)
3 No. 16 5 No. 16 9 No. 16 3 No. 12	MIL-C-24217	3/4" to 2" Circle Diameter 1/8" diameter pin
14 No. 16 24 No. 16 3 No. 8 3 No. 4 3/12 with 3/8		1-1/4" to 3" Circle Diameter 3/16" diameter pin
3 No. 16 4 No. 16 7 No. 16	MIL-C-24231	1-1/4" to 3" Circle Diameter Hook type
14 No. 16	MIL-C-24231	2" to 4-3/4" Circle Diameter Hook type

13.6 Outboard Circuit Check-Out Procedures

Use the following procedures to check outboard electrical circuits for shorts, opens, or unacceptable insulation resistance.

CAUTION

PRIOR TO TAKING INSULATION RESISTANCE READINGS ON ANY CIRCUIT, CHECK APPLICABLE SYSTEM CIRCUIT DRAWINGS TO ASSURE THAT THE SYSTEM CAN BE SUBJECTED TO THE 500-VOLT MEGGER TEST. WHERE POSSIBLE, READINGS SHOULD BE TAKEN WITH A 500 VOLT DC MEGOHMMETER.

1. Check continuity of outboard circuitry by switching on equipment to determine operability. For components not readily operable, ground conductors to hull in sequence. Check out conductors using a buzzer.

2. Take insulation resistance readings on the outboard electrical circuit at an accessible point through the inboard terminal box of the hull penetrator. This will also check out the inboard terminal box connections. In systems where the electrical hull penetrator wiring runs directly to the "black box", perform this check-out where it plugs into the black box.

Where possible, take the above readings with the submarine at dockside.

3. Megger conductor to remaining conductors grounded (i.e., pin 1 to pins 2, 3 and 4 grounded, etc) by isolating one conductor and "bunching" remaining conductors connected to the ship ground. Continue readings in sequence.

13.6 (Continued)

4. Disconnect plug at outboard component and ground plug to ship's hull. Megger outboard component.

NOTE

PLACE PROTECTIVE PLUG AND RECEPTACLE CAPS ON CONNECTORS FOLLOWING DISCONNECT. REMOVE CAPS ONLY WHEN CHECKING CIRCUITRY.

5. Disconnect plug at outboard hull penetrator. Ground component plug shell to hull and megger outboard harness.

6. Ground penetrator plug shell to hull and megger outboard harness.

7. Disconnect connections at inboard terminal box or black box plug and megger circuitry from penetrator receptacles to inboard disconnect point.

8. By following the above meggering continuity and insulation resistance sequence, the problem area will be detected at some point during the sequence. The troublesome outboard component, harness, or penetrator should be inspected for possible cleaning, repair or replacement.

13.7 Pressure-Proof Connector Groundings

Grounding straps should be installed on the coupling rings of outboard connectors when the electrical resistance between the coupling ring and the local ground (hull structure) is greater than 5 ohms. All in-line connectors should be grounded.

Perform the following steps in the sequence indicated to ground the outboard connector assembly:

1. Check the resistance between the connector coupling ring and local ground with a volt-ohmmeter. If the resistance is greater than 5 ohms, a ground strap is required. See Figures 13-3 and 13-4.

2. If the connector requires grounding, clean corrosion deposits from the plug coupling ring with a wire brush.

3. Fabricate and install a coupling ring ground strap in accordance with the method shown in Figure 13-4.

4. Determine the location of a local hull structure grounding point. The terminal lug can be grounded with a method shown in Figure 13-4.

5. Determine the required length of the 0.051 inch solid Monel ground wire.

6. Bend the Monel wire into a "U" shape at each end to an approximate 3/32 inch outside radius and 3/8 inches long.

7. Insert the "U" shaped wire into the Monel terminal lug.

13.7 (Continued)

8. Insert the flat side of the terminal lug crimp collar toward the upper indentor f the Thomas & Betts WT-137 crimping tool. The seam side of the terminal lug will face toward the lower indentor.

9. Center the terminal lug crimp collar in the N30 indentor notch (innermost notch) and fully crimp the lug.

10. Visually inspect the crimped connector for alignment of wire and soundness of the crimp joint.

11. Repeat Steps 6 through 10 at the other end of the ground wire.

12. Fasten the coupling ring terminal lug to the ground strap with the screw and self locking nut specified in Figure 13-4.

13. Run the grommet wire to the ground point.

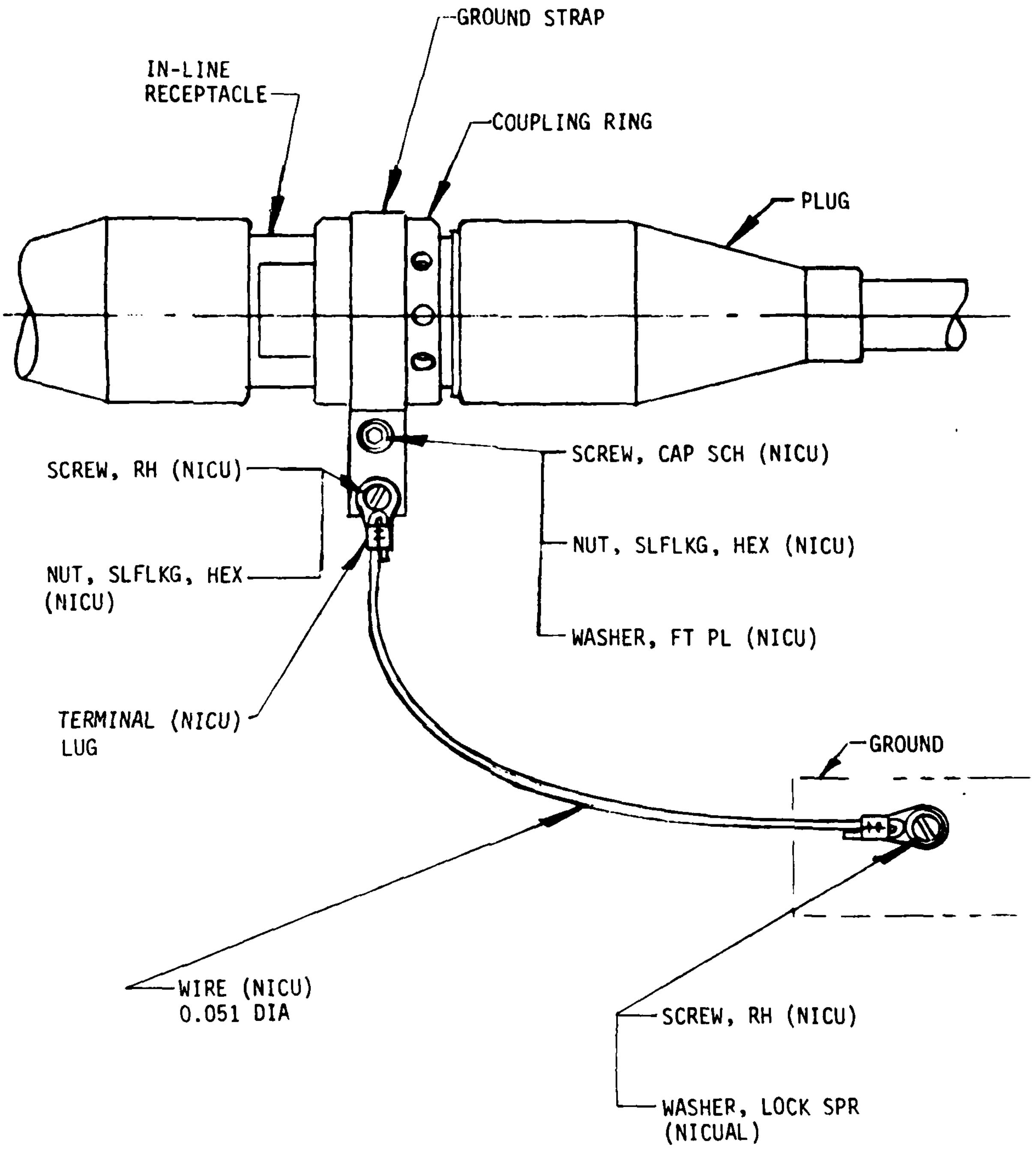
14. If the terminal lug is to be terminated in a tapped hole, drill the hole with a No. 36 size drill (.1065 inch diameter). Tap the hole as specified in Figure 13-4. Do not drill into pressure hull.

15. If the terminal lug is to be terminated with a ground strap as shown in Figure 13-4, drill the hole in the grounding strap to suit the grounding bolt to be used.

16. Install the specified round head screw and lockwasher in the terminal lug and terminate the lug to the grounding point. If the lug is terminated to the grounding strap, use the specified round head cap screw and a self locking hex nut to terminate the lug. Terminate the grounding strap to the grounding bolt.

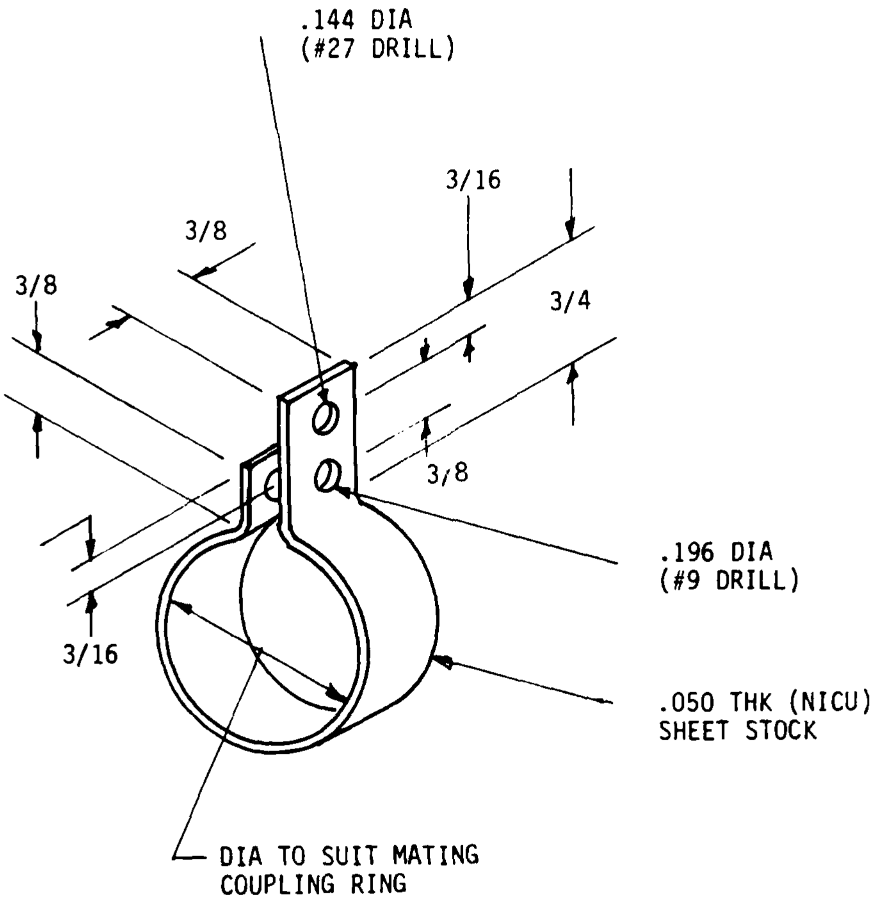
13.7 (Continued

17. Check the resistance between the connector coupling ring and the ground point with a volt-ohmmeter to determine that a proper ground has been made (less than 5 ohms).



NOTE: NICU is Monel.

FIGURE 13-3 OUTBOARD CONNECTOR GROUNDING METHOD



COUPLING RING GROUND STRAP

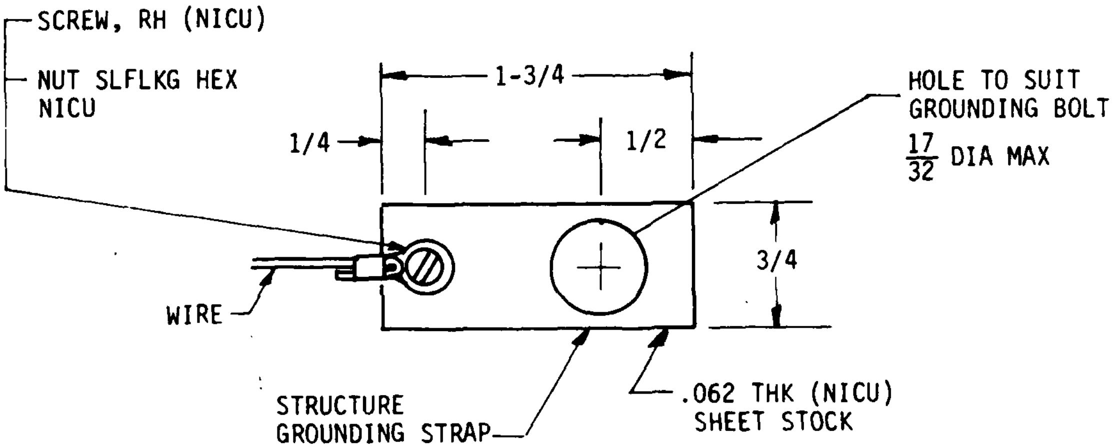


FIGURE 13-4 GROUND STRAP DETAILS

13.8 Special Precautions for Handling of Outboard Cable Harnesses

13.8.1 Harness Plug Disconnection - Before disconnecting an outboard plug, ensure that the cable has sufficient slack in front of the first cable clamp or fastener, so that the cable is not bent excessively or twisted. Unclamp or unband the cable if necessary to provide the needed slack.

13.8.2 Protecting Installed Exposed Cables - Do not open the outboard cable pans or remove protective cable covers unless absolutely necessary. If the cables are exposed, provide temporary protection so that the cables will not be damaged.

13.8.3 Protecting Removed Cables - When removing outboard equipment (waterborne or otherwise) avoid dragging the cable around sharp corners or edges and avoid contact with barnacles as this can damage the cable jacket. Do not use the cables or plugs as "handles" to move attached equipment, or as fastening points for lifting slings.

13.8.4 De-Energizing Cables Before Handling - Do not disconnect outboard cables until certain that the circuit has been de-energized. In certain circuits, male pins on receptacles can be electrically "hot" when disconnected. This is particularly true of the electrical hull penetrators and junction boxes.

13.8.5 Capping Plugs and Receptacles - Whenever an outboard cable harness is disconnected, immediately place a nonferrous metal protective cap on the plug and receptacle to keep out foreign material and prevent damage. Do not use plastic dust caps. Do not disconnect cables unless necessary.

13.8.6 Testing Precautions - Before meggering connected cable harnesses or test points in the hull penetrator terminal boxes, be sure the connected equipment can withstand the applied megger voltage.

13.8.7 Cleaning Contaminated Plugs and Receptacles - If receptacle or plug faces become contaminated by salt water or other foreign material, swab out the receptacle or plug with distilled water or alcohol, then dry it with dry nitrogen. Repeat the operation as necessary until adequate insulation resistance values are obtained.

13.8.8 Connector Mating Precautions - When mating plug to receptacle connectors, exercise caution tc ensure that the proper plug is mated to the proper receptacle. If they are physical matched but electrically mismatched, the equipment can be damaged. Attempting to mate plugs or receptacles having non-standard key orientations will physically damage the plug and/or receptacle. These keyway deviations may not be readily discernible to the eye. In addition, certain right angle plugs are specially oriented for the cable exit; attempts to force them into contact will damage the plug and/or receptacle.

13.8.9 Securing Excess Outboard Cables - When replacing an outboard cable harness carefully coil any slack in a protected area in the ship's structure where it will not be exposed to excessive water turbulence and secure it with banding or other specified fasteners so that it is adequately supported and restrained. Do not "sheepshank" the cable or bend the cable back on itself. Conform to the minimum bend radius for the specific cable type.

13.8.10 Re-Banding Instructions - When re-banding cables, do not tighten the bands excessively so that they cut into or bunch the cable jacket. For re-installing outboard cables see Paragraph 13.2.

13.9 Troubleshooting

This section contains troubleshooting instructions and information for the inboard and outboard electrical cabling and electrical hull penetrator components. Troubleshooting of the components is generally limited to visual and physical inspection of the components and electrical checks of the harnesses and penetrators to isolate the failure areas.

13.9.1 <u>General System Troubleshooting</u> - The electrical hull penetrators and external cable assemblies are designed to withstand the submarine sea water environment. In addition, the support and protective devices provided minimize the possibility of physical damage under ship operating conditions. However, violent sea forces, mechanical stresses, and the entry of foreign material into the cable ways can cause physical damage to an outboard component.

Primary considerations pertinent to troubleshooting are visual inspection of cables and penetrators, verification that support and protective devices have not deteriorated or become loosened from their attachement structures, and checking connectors for sea water barrier integrity. The entry of even a minute amount of sea water into a cable, connector or cable splice will decrease insulation resistance, corrode connector pins, or cause unwanted electrical paths between individual conductors. Careful inspection will often lead the technician to the cause of failure of a cable run without the need for electrical tests, which can be involved and time consuming.

13.9.1 (Continued)

The first step in troubleshooting a cable run suspected of being faulty is to make a close visual and physical inspection of the enture run; some specifics are listed below:

1. Wherever individual cables, cable bundles, protective rubber sheeting, cable transition pieces, splices, and banding straps are accessible, look for:

   (a) punctured or abraded cable jackets,
   (b) punctured, torn, or missing protective rubber sheeting,
   (c) loose or damaged protective cable transition pieces,
   (d) cuts or separations in cable splice boots, and
   (e) loose, damaged, or missing banding straps or strap channeling.

NOTE

IF ANY OF THE PROTECTIVE SHEETING, TRANSITION PIECES, OR BANDINGS ARE DEFECTIVE, THEY SHOULD BE REPLACED; DURING REPLACEMENT, SOME SECTIONS OF INDIVIDUAL CABLES AT THE PERIMETER OF A CABLE BUNDLE CAN BE EXPOSED FOR INSPECTION. CABLES IN THE CENTER OF A CABLE BUNDLE ARE LESS VULNERABLE TO DAMAGE AS THEY RECEIVE ADDITIONAL PROTECTION FROM SURROUNDING CABLES.

13.9.1 (Continued)

2. Examine the cable support devices. If a support such as an angle bar is loose, the individual cables can be flexed and stressed and cables bend radii can be considerably shortened; shortened bend radii can cause cable jacket rupture, damage to shield braid, breakdown of the internal insulating material, or conductor breakage.

3. Inspect the molded boot of connector assemblies for boot separation from the connector body.

4. Verify that cable connector plugs are securely tightened to their mating receptacles. If there are any evidences that the integrity of the connector sea water barrier has been lost, unmate the plug and examine the O-ring gaskets, seal surfaces, and O-ring grooves. Inspect for corrosion of connector pins and evidence of sea water residue within the connector cavities. Clean or replace O-rings as inspection dictates.

When the cause of trouble in a cable run cannot be determined by visual and physical inspection, electrical tests are required to isolate the defect to a specific cable, penetrator, connector, or cable splice. The outboard electrical/electronic systems must meet the insulation resistance requirements. Troubleshooting by electrical test is described below. For systems using special cabling arrangements, detailed procedures are provided; for other cable runs using conventional connectorized components which provide easy access to the electrical paths, general

13.9.1 (Continued)

procedures applicable to all of these cable runs are provided. The test equipment identified below is required.

(a) 500-volt dc or 50-volt dc megger (whichever is applicable to the system being tested) for testing insulation resistance.
(b) Multi-range dc ohmmeter for measuring conductor resistance.
(c) Buzzer and battery test set for checking conductor continuity.
(d) Test plugs and test receptacles to provide convenient electrical connection to penetrator and connector contacts.

CAUTION

Mate electrical contacts with spare pins and sockets, as applicable.

13.9.2 General Electrical Tests for Fully Connectorized Harnesses

The electrical hull penetrators and outboard cables that are fully connectorized are the easiest to troubleshoot since the cables can be disconnected from the penetrators and outboard components for testing without disturbing splices or molded connections.

13.9.2 (Continued)

WARNING

WHEN PERFORMING TESTS OR OTHERWISE WORKING ON PENETRATORS AND CABLING, ASSURE THAT ALL WIRING IS DE-ENERGIZED AND ISOLATED FROM POWER AND SIGNAL SOURCES AND THAT THE DISCONNECT DEVICES ARE TAGGED WITH APPROPRIATE SAFETY NOTICES. OBSERVE ALL PRECAUTIONS DESCRIBED IN CHAPTER 18 OF UNITED STATES NAVY SAFETY PRECAUTIONS, OPNAV 34P1.

NOTE

FOR THE FOLLOWING TROUBLESHOOTING PROCEDURES, IT IS ASSUMED THAT THE ASSOCIATED INBOARD CABLING AND SYSTEM COMPONENTS HAVE BEEN CHECKED OUT AND FOUND TO BE IN SATISFACTORY OPERATIONG CONDITION.

1. Obtain applicable system diagrams and wiring tables and give penetration numbers, lead numbers, connector types, and connector contact wiring.

2. Determine if the penetrators and cables can be subjected to 500-volt dc megger tests; if not, use a 50-volt megger.

13.9.2 (Continued)

CAUTION

TO AVOID DAMAGE TO CONNECTOR PLUGS AND RECEPTACLES, ALWAYS INSTALL PROTECTIVE CAPS WHEN CONNECTORS ARE NOT PROTECTED BY THEIR MATING PARTS.

3. Take insulation resistance readings on the penetrator and connected outboard cabling at an inboard terminal box if the box is available and assessible. If a terminal box is not available or is inaccessible, connect a test plug to the inboard receptacle of the penetrator and take the insulation resistance readings at that point. Megger individual conductors to ship ground. Proceed in contact number sequence until all conductor paths have been tested in the same fashion. This procedure will locate poor insulation resistance between individual conductors and ground.

4. If unsatisfactory readings are obtained in Step 3 above, unmate the outboard connector plug at the associated hull penetrator and repeat insulation resistance tests.

5. If the insulation resistance between conductors or conductors and ground is unsatisfactory, the trouble is in the penetrator. If the insulation resistance for each conductor and conductor to ground is satisfactory, the trouble is in the outboard cable or outboard equipment.

13.9.2 (Continued)

6. Disconnect outboard cable at the equipment end and connect a test receptacle to the cable plug. Take insulation resistance readings between the plug's contact and between each contact and the plug shell; do this at both ends of the cable. If the readings are satisfactory, check cable for circuit continuity. If the continuity check is satisfactory, the trouble is in the outboard component. If any insulation resistance or circuit continuity of the cable is unsatisfactory, replace the cable assembly. In all cases, check the insulation resistance at the contacts of the outboard component connector.

13.9.3 TRIDENT AN/BQQ-6 Sonar System Spherical and Line Array Hydrophones

Since the outboard cables for the spherical and line array are hard wired externally to the penetrators and hydrophones they cannot conveniently be disconnected for continuity and insulation resistance tests. Make tests at the inboard connector of the penetrator.

NOTE

FOR THE FOLLOWING TROUBLESHOOTING PROCEDURE, IT IS ASSUMED THAT THE INBOARD CABLES AND ASSOCIATED SONAR EQUIPMENT IS OPERATING SATISFACTORILY BUT THERE IS NO RESPONSE OR AN ERRATIC RESPONSE FROM A PARTICULAR HYDROPHONE.

1. Unmate the inboard plug from the penetrator and install a test plug.

13.9.3 (Continued)

2. Refer to the system cabling diagram and determine the cable number for the affected hydrophone.

3. Expose the outboard splice in the affected cable and verify that the cable tag number (near the splice) agrees with the number taken from the system diagram. The splices are located in the area forward of the 40-foot long sonar sphere cable trunk.

4. Sever the cable near the splice on the penetrator side of the splice. Separate the cable conductors to assure that they were not shorted together when the cable was severed.

5. Determine which connections on the test plug feed the affected cable; use the system cabling diagram and wiring tables for this purpose.

6. At the penetrator test plug, measure the insulation resistance between the contacts and between each contact and ground of the affected cable.

7. If the readings are satisfactory, check the affected cable's circuit continuity by twisting both cable conductors together at the severed end and measuring continuity across the associated contacts at the inboard plug.

8. If the insulation resistance is low or there is no conductor continuity, end seal the defective cable and substitute a spare cable for the defective one. The spare cables, are connected to spare penetrator contacts, the loose end is end-sealed, and a length of the loose end is stowed in the bow dome cable trunk or in the penetrator cavity.

13.9.3 (Continued)

9. After the spare cable from the penetrator is spliced to the cable from the hydrophone, the deactivated inboard conductors must be disconnected and the associated inboard spare conductors must be connected to the sonar system; that is accomplished in the applicable array junction box in the sonar equipment space.

10. If the section of the outboard cable connected to the penetrator is found to be in satisfactory condition, the trouble is most likely to be in the splice or the hydrophone section of the cable or the splice.

11. Cut the splice from the cable and check the hydrophone end.

12. If the hydrophone section is found to be unsatisfactory, install a new hydrophone and cable assembly and splice the cables together.

13. If the hydrophone section is found to be satisfactory, the problem is in the splice; resplice the cables.

Some cables between the electrical hull penetrators and their associated hydrophones are connectorized at their Electrical Hull Penetrator ends and hard wired at their hydrophone ends. Therefore, troubleshooting is limited to insulation resistance and continuity tests on the penetrators and checking

(Continued)

the cable-to-penetrator connector for damage and corrosion. If trouble cannot be isolated to a penetrator or outboard connector, the outboard cable, together with the hydrophone, must be removed for repair or replacement.

13.10 Typical Outboard Cable Harness Installation Record

This procedure establishes the method for completing records of outboard cable harness installation.

13.10.1 Departments Affected/Responsibilities - The following departments shall be responsible for adherence to the requirements of this procedure:

(a) Installation - Installation trades shall complete records of cable installation.

(b) Quality Assurance - Inspection shall complete and file completed records of cable installation with applicable work authorization.

13.10.2 Applicable Documents - The following documents of the latest issue, unless indicated by specific revision, form a part of this procedure to the extent specified.

"Cable Hook-Up Check-Off List"*

13.10.3 Procedures - Records of Outboard Cable Installation

One (1) copy of Table 13-2 shall be completed for the installation of each outboard cable. Cable lead number and drawing number shall be recorded on Table 13-2:

(a) The forms shall be signed to indicate compliance with drawing and procedure requirements.

(b) The forms shall be signed and dated by a QC inspector to certify satisfactory completion of each item.

One (1) copy of Table 13-2 and a suitable Test Form shall be completed by the Installation Trade and QC Inspector.

The Trade Foreman shall then sign and date Table 13-2 and the Test Form for trade acceptance of the installation.

Upon completion of the cable installation, the completed copies of Table 13-2 and Cable Hook-Up Check-Off List shall be forwarded to the Shipyard QC office for review and filing.

* Shipyard Document.

TABLE 13-2 - OUTBOARD CABLE HARNESS INSTALLATION RECORD

Lead No.__________ Drawing No.__________ Rev.______

Cable Type __________ Length __________

Step	Installation Trade Initials	QC Initials	Date	Remark
Cable Tagged Acceptable	______		____	
Proper Lead Number	______			
Cable Jacket Inspected	______			
Cable Connectors Inspected	______			
Component/EHP Connector Inspected	______			
Connector O-Rings Inspected	______	______		
Connectors Properly Mated	______	______		
Cable Properly Installed	______	______		
Cable Bending Radius Not Exceeded	______	______		
Cable Electrical Checked From First Point Inside Hull	______	______		Record On Test Form

Trade Signature __________ Date__________

QC Signature __________ Date__________

Trade Supervisor Signature __________ Date__________

SECTION 14

QUALITY CONTROL CONSIDERATIONS

LIST OF TABLES

14.1 Introduction

The most urgent problem associated with failure of underwater components has been the control of quality during the various stages of fabrication, handling, shipping, and installation. While poor design has been responsible for component failures, many equipment users contacted in the past year attribute their failures to inadequate manufacturing and installation quality control.

14.2 Quality Control Considerations

Quality control procedures must be envoked at the plant of the manufacturer of cables and connectors (plugs and receptacles) and at the manufacturer of the harness. The manufacturer must maintain the following controls:

a. Control and identification, stocking, issue of all materials received in plant; as well as material verification of all materials received.

b. Provide and maintain a description of procedures for control of quality. (See Section 12.)

c. Maintain a procedure to assure that the latest applicable drawing, technical requirement, and contract change information will be available at the time of inspection.

d. Maintain calibrated gages and other measuring and testing devices necessary to assure that components conform to specification requirements.

14.2 (Continued)

e. Establish and maintain inspection at appropriately located points in the manufacturing process to assure continuous control of quality.

f. Establish and maintain packaging devices for properly handling and adequately protecting the components in-plant.

g. Inspect and test the completed components. (See Section 12).

h. Establish and maintain a system for identifying, serializing and certifying completed components.

i. Provide adequate procedures and instruction for control of stored supplies and finished components.

j. Provide procedures for protecting the quality of components during transit.

k. Maintain adequate quality control records throughout all stages of contract performance of inspections and tests; including checks to assure accuracy of inspection and testing equipment and other control media.

l. Establish and maintain a failure reporting and analysis program.

Control of quality can be assured by the inclusion of requirements in the proposed Military Specifications written for connectors, cables and harnesses. In addition, a wiring, molding, handling, inspection and test procedure manual must be prepared for cable harnesses. A manual should also be prepared detailing connector and harness installation, check-out and maintenance practices. (See Section 10).

14.2 (Continued)

A number of quality deficient areas have persisted in hardware used over the years. These are listed in Table 14-1, along with the applicable quality control document which should be used to minimize these problem areas.

TABLE 14-1

Quality-Control Documents Applicable to Connector/ Harness Problem Areas

No.	Potential Areas of Quality Deficiency	Applicable Controlling Document
1	Cable jacket/boot bond	MM
2	Boot/plug shell bond	MM
3	Conductor/contact crimp	MM
4	Preparation for terminating conductor	MM
5	Cable seal boot voids	MM
6	Pinched cable jacket during molding	MM
7	Plug seal surface damage	CS-IM
8	Coupling ring threads	CS-IM
9	Receptacle threads	CS-IM
10	Socket contact insulator damage	CS-IM
11	Potting compound in socket contacts	MM
12	Socket contacts recessed inside insulator	MM
13	Improper mating of plug/receptacle	CS
14	Bent pin contacts	CS-IM
15	Porous or cracked receptacle to component weld	IM
16	Damaged or improperly molded O-rings	CS-IM
17	Improperly sized O-ring	CS-IM
18	Conductor to contact cold soldered joint	MM
19	Improperly positioned polarizing key	CS-MM
20	Improperly positioned polarizing keyway	CS-MM
21	Oversized pin contact gasket	CS
22	Improperly bonded pin contact gasket	CS
23	Damaged cable jacket	CAS-HS
24	Conductor kinking or break in cable	CAS-HS
25	Damaged socket contact retention spring	CS-IM

TABLE 14-1

(Cont'd)

No.	Potential Areas of Quality Deficiency	Applicable Controlling Document
26	Improperly dimensioned plug and receptacle	CS
27	Insulator voltage breakdown	CS-CAS-HS-MM
28	Cable jacket "wear through"	IM
29	Conductor breakage due to sharp bend radius	IM-HS-CAS
30	Foreign particles at plug/receptacle interface	IM
31	Contaminated potting materials	MM
32	Gasket damage due to use of improper solvents	IM-MM
33	Foreign particles on seal surfaces	IM
34	Conductor breakage due to axial cable load	IM-CAS-HS
35	Improper termination of cable braid shields	MM-HS
36	Dislodged plug keys	CS
37	Improper polarization of insulations to plug shell	CS-MM
38	Contact insulation damage due to excessive weld temperature	IM
39	O-ring damage due to insufficient lubrications	CS-IM
40	Improperly positioned contact gaskets	CS
41	Conductor migration during cable end sealing	MM

KEY:

MM = Wiring and Molding Manual.

IM = Installation Manual.

CS = Connector Military Specifications.

HS = Harness Military Specifications.

CAS = Cable Military Specifications.

(BLANK)

SECTION 15

TYPICAL FAILURE MODE AND EFFECTS ANALYSIS (FMEA) FOR CONNECTORS AND CABLE HARNESSES

LIST OF TABLES

(Blank)

15.1 Introduction

A Failure Mode and Effects Analysis (FMEA) is an important tool for an engineer in the design of a system and its components. It is a basic tool for evaluating a system or component and improving its reliability. Use of an FMEA at the proper time during systems development can reveal design deficiencies which would require costly design modifications. An FMEA can also point out potentially hazardous conditions in the design. One of the best times for an FMEA is during the formal design review period. It is at this time that appropriate engineering action can be taken to correct design deficiencies.

"The purpose of the FMEA is to avoid costly modifications by ferreting out latent design and operational deficiencies in early design and testing phases of component and subsystem development and to ensure a high level of achieved reliability before the initiation of quantity production. An additional objective is the determination of the critical failure modes that have a serious effect on the successful completion of a mission and on the safety of the crew (and passengers)". (Reference 15-1).

15.2 Typical Failure Mode and Effects Analysis for Connectors and Cable Harnesses

The first column in Table 15-1 provides a listing of all of the components which are used to assemble the connector plug and receptacle. The second column lists the possible causes of failure of each of the components. The third column suggests tests that can be conducted to alleviate these possible causes of failure. The fourth column indicates the level of severity should a failure occur, and the fifth column indicates the probability of failure of the individual components. The last column provides recommendations for eliminating the possible failures of the connector assemblies. Table 15-2 provides a listing of the connector components and indicates their function in the connector design.

Table 15-1

FAILURE MODE AND EFFECTS ANALYSIS**

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode Index	Item (a) Failure/ Function Loss / Effect	Possible Failure Causes	Level Of Severity Test Suggestions	1-2-3-4*		Probability Of Failure Remarks & Recommendations
	PLUG ASSEMBLY					
1	PLUG SLEEVE					
	(a) sea water entry thru plug sleeve	(a) corrosion	Accelerated life	4	1	Ground connector
	(b) sea water entry past plug-to-receptacle O-ring seal.	(b) improper fabrication; O-ring seal surface damage.	Product examination	4	1	Add a secondary gasket seal to the design.
2	COUPLING (RING)					
	(a) improper mating/unmating of plug assembly	(a) corrosion	Accelerated life	4	1	Ground connector
	(b) sea water entry due to improper mating of plug	(b) improper machining of threads	Product examination	4	1	
3	SOCKET CONTACT					
	(a) open circuit	(a) missing, damaged spring;	Product examination	4	1	
		oversize contact bore;	Product examination	4	1	
		contaminated contact;	-	4	1	
		broken contact	-	4	1	
						(cont'd.)

* 1 - Lowest; 4 - Highest

** Reference 15-2

TABLE 15-1 (cont'd.)
FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Index	Failure Mode: Item (a) Failure/ Function Loss / Effect	Possible Failure Causes	Level Of Severity: Test Suggestions	1-2-3-4*		Probability Of Failure: Remarks & Recommendations
(CONT'D)	SOCKET CONTACT					
3	(b) damaged socket contact	(b) sea water entry past plug-receptacle seals;	Hydrostatic pressure	4	1	
		sea water entry thru cable jacket puncture or molded boot seal	Hydrostatic pressure	4	1	
4	SLEEVING					
	(a) damaged sleeving allowing rubber into socket contact internals	(a) improper QC	Product examination	2	1	
5	PLUG CAP (PROTECTIVE)					
	(a) O-ring seal surface damage	(a) protective cap not used when plug unmated	-	4	3	Protective cap should always be installed when plug is unmated from receptacle.
						(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)
FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*	Probability Of Failure
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions		Remarks & Recommendations
(CONT'D)					
6	SOLDER				
	(a) open circuit	(a) cold soldered joint	Product examination, Continuity	4	1
	(b) broken conductor	(b) improper soldering due to extreme wicking of solder up conductor	Shock, Vibration	4	1
7	MOLDED RUBBER BOOT				
	(a) sea water entry into plug assembly	(a) cracked boot, improper material, overstressed;	Accelerated life	4	1
		material reversion;	Accelerated life	4	1
		voids in material; improper molding	Hydrostatic pressure	4	1
					(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*		Probability Of Failure
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
8	BOOT-TO-PLUG ADHESIVE					
	(a) sea water entry into plug assembly	(a) improper QC in fabrication;	Accelerated life	4	3	
		use of overage adhesives;		4	1	
		use of improper adhesives;		4	1	
		improper preparation of metal surfaces-sandblasting, cleaning;		4	2	
		contaminated sealing surfaces		4	2	
9	BOOT-TO-CABLE JACKET ADHESIVE					
	(a) sea water entry into plug assembly	(a) improper QC in fabrication;	Accelerated life	4	1	
		use of improper adhesive;		4	1	
		improper preparation of cable jacket surfaces - roughing, cleaning;		4	1	
		contaminated sealing surfaces		4	1	
						(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*	Probability Of Failure	
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
10	CABLE (FSS-2)					
	(a) sea water entry thru punctured cable jacket	(a) improper handling, packaging, damage in service	Hydrostatic pressure	4	2	Eliminate overall shield, redesign cable
	(b) broken conductor, open circuit	(b) improper handling, fabrication defect (Z kink)	Continuity	4	1	
	(c) low insulation resistance	(c) insulation defect, improper wiring	Withstanding voltage, insulation resistance	4	1	
11	<u>RECEPTACLE ASSEMBLY</u>					
11-A	RECEPTACLE BODY					
	(a) sea water entry thru receptacle body	(a) corrosion	Accelerated life	4	1	
	(b) sea water entry past O-ring seal	(b) improper fabrication;	Hydrostatic pressure	4	1	
		O-ring seal damage		4	1	
	(c) sea water entry due to improper mating of plug to receptacle	(c) improper machining of threads	Product examination	4	1	
11-B	PIN					
	(a) loss of pin from body resulting in loss of insert polarization	(a) improper welding	Product examination	4	1	
						(cont'd.)

* 1 Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*	Probability Of Failure
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
12	MOLDED INSERT ASSEMBLY					
12-A	PIN CONTACT					
	(a) open circuit	(a) undersize contact diameter;	Product examination	4	1	
		contaminated contact;		2	1	
		bent contact;		4	1	
	(b) damaged pin contact	(b) sea water entry past plug to receptacle seal		4	1	
12-B	MOLDED INSERT					
	(a) sea water entry past insert	(a) improperly fabricated, damaged O-ring groove;	Product examination	2	1	This insert protects the component internals from sea water should the cable be damaged or the plug-to-receptacle seal fail.
		improperly molded insert resulting in loss of bond to pin contacts	Improper QC	2	1	
						(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*		Probability Of Failure
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
12-C	WIRE					
	(a) broken conductor, open circuit	(a) improper handling, fabrication defect (Z kink)	Continuity	4	1	
	(b) low insulation resistance	(b) insulation defect, improper wiring	Withstanding voltage, insulation resistance	4	1	
12-D	SOLDER					
	(a) open circuit	(a) cold soldered joint	Product examination, Continuity	4	1	
	(b) broken conductor	(b) improper soldering due to extreme wicking of solder up conductor	Shock, Vibration	4	1	
13	RETAINING RING					
	(a) broken or missing ring	(a) improper QC	Product examination	2	1	
						(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity	1-2-3-4*		Probability Of Failure
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
14	O-RING (PLUG-TO-RECEPTACLE SEAL)					
	(a) sea water entry into connector	(a) missing, O-ring; damaged O-ring; improper O-ring material	Hydrostatic pressure	4 4 4	1 1 1	Provide a secondary plug-to-receptacle gasket seal in the design
15	O-RING (INSERT-TO-RECEPTACLE BODY)					
	(a) sea water entry past molded insert assembly	(a), missing, damaged O-ring	Product examination	2	1	This gasket protects the component internals from the sea water should the cable be damaged or the plug-to-receptacle seal fail.
16	NYLON INSERT					
	(a) plug unmated from receptacle	(a) missing, worn insert	Product examination	4	1	
						(cont'd.)

* 1 - Lowest; 4 - Highest

TABLE 15-1 (cont'd.)

FAILURE MODE AND EFFECTS ANALYSIS

CONNECTOR ASSEMBLY - MIL-C-24231

Failure Mode		Possible Failure	Level Of Severity 1-2-3-4* Probability Of Failure			
Index	Item (a) Failure/ Function Loss / Effect	Causes	Test Suggestions			Remarks & Recommendations
(CONT'D)						
17	CAP (PROTECTIVE)					
	(a) O-ring damage	(a) protective cap not used when plug unmated	-	4	3	Protective cap should always be installed when plug is unmated from receptacle.

* 1 - Lowest; 4 - Highest

TABLE 15-2 - CONNECTOR FUNCTIONAL DESCRIPTION
MIL-C-24231

Index	Item	Functional-Description
1	Plug Sleeve	Housing for cable-to-socket contact wiring.
2	Coupling	Fastens and retains plug to receptacle.
3	Socket Contact	Terminates cable conductors and provides electrical contact with pin contact located in receptacle.
4	Sleeving	Prevents polyurethane rubber from entering socket contact spring and cavity when molding the plug.
5	Plug Cap (Protective)	Protects the plug seal surfaces, coupling threads, plug sleeve, and socket contacts when the plug is unmated from the receptacle.
6	Solder	Fastens and provides electrical contact between conductors and socket contacts.
7	Molded Rubber Boot	Provides pressure-proof seal between cable and plug; cable strain relief; and insulates socket contacts.
8	Boot-To-Plug Adhesive	Bonds rubber boot to plug sleeve to provide seal.
9	Boot-To-Cable Jacket Adhesive	Bonds rubber boot to cable jacket to provide seal.
10	Cable	Provides electrical circuit between transducer and electrical hull penetrator.
11-A	Receptacle Body	Housing for receptacle pin contacts.
11-B	Pin	Polarizes insert assembly to receptacle body.
12-A	Pin Contact	Terminates molded insert assembly conductors and provides electrical contact with socket contacts located in plug.
12-B	Molded Insert	Insulates pin contacts and provides a pressure-proof sea water barrier should the plug/receptacle seal fail or the cable be puntured or severed.
12-C	Wire	Provides electrical circuit between inboard component and receptacle pin contacts.
12-D	Solder	Fastens and provides electrical contact between wires and pin contacts.
13	Retaining Ring	Retains molded insert assembly in receptacle body.

(cont'd.)

TABLE 15-2

(Cont'd)

Index	Item	Functional-Description
14	O-Ring (Plug-to-receptacle)	Provides seal between plug and receptacle.
15	O-Ring (Insert to receptacle)	Provides seal between molded insert and receptacle body.
16	Nylon Insert	Provides locking device for plug coupling.
17	Cap (Receptacle Protective)	Protects the O-ring gasket; threads; pin contacts; and insert when the plug is unmated from the receptacle.

REFERENCES

15-1 Arnzen, H.E., "Failure Mode and Effect Analysis; A Powerful Engineering Tool for Component and System Optimization" Fifth Reliability and Maintainability Conference, N.Y., N.Y., Sponsored by American Institute of Aeronautics and Astronautics, dated July 18-20, 1966.

15-2 Haworth, R.F., "Electrical Cable and Connector Design for the Ametek/Straza TR-215 ( ) Sonar Projector", EBDivision Report No. U 443-78-036, dated September 22, 1978, Contract No. N66001-77-C-0220.

(BLANK)

BIBLIOGRAPHY

A1. Aamodt, T., "Seals for Electrical Equipment Under Water Pressure and Fusion of Marlex to Polyethylene by a Molding Process", Bell Telephone Laboratories, Report No. 56-131-41, August 16, 1956.

2. Aamodt, T., "Seals for Ocean Bottom Equipment Containers", Bell Telephone Laboratories, Report No. MM-61-213-26, February 28, 1961.

3. Alexander, D.C., "The Fatigue Life of Stranded Hookup Wire", Second Annual Wire and Cable Symposium, AD 656 334, 1953.

4. Athey, R.J., "Water Resistance of Liquid Urethane Vulcanizates", E.I. DuPont Elastomer Chemicals Department, Bulletin No. 4, April, 1965.

5. Arnzen, H.E., "Failure Mode and Effect Analysis: A Powerful Engineering Tool for Component and System Optimization", Fifth Relaibility and Maintainability Conference, N.Y., N.Y., sponsored by American Institute of Aeronautics and Astronautics, July 18-20, 1966.

6. Armbruster, R.L. & Edgein, K.R., "Final Test Report Underwater Mateable Connectors", Document No. 3742, Honeywell Marine Systems Center, Seattle, Washington, dated 28 September 1979.

Anon.

1. "Underwater Cable, Connector, Penetrator Problem Survey", Northrup Systems Laboratories, Palos Verdes, California, 90274, Report No. NORT 68-447.

2. "Basic Guidelines for Development and Use of Underwater Cables, Connectors and Penetrators", Northrup Systems Laboratories, Palos Verdes, California, 90274, January, 1969.

3. "Cable Systems for Oceanographic Instruments in Submersibles", Manned Submersibles and Underwater Surveying, U.S. Naval Oceanographic Office, Washington, D.C., Page 91-102.

4. "Glass and Ceramic Sealing Alloy Tubing", Electro-mechanical Design, November, 1965.

5. "Marine Materials", Nickel Topics, Volume 23, No. 3, International Nickel Company.

B1. Beaubien, L.A., et al, "Behavior of Materials in a Subsurface Ocean Environment", Naval Research Laboratory, Washington, D.C., NRL Report No. 7447, July 14, 1972.

2. Bolger, Dr. J.C., "Selection of Connector Potting Compounds", Second Annual Connector Symposium, Cherry Hill, New Jersey, October 21-22, 1969.

3. Bridges, R.M., "Undersea Cable System Design for the Eniwetok BMILS Installation", Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

4. Briggs, E.M., et al., "A Wet and Dry Deep Submergence Electrical Power Transmission System", Final Report, Southwest Research Institute Project No. 03-25707-01, July 25, 1969.

5. Briggs, E.M., "The Design of a 4160-Volt Deep Sea Wet and Dry Connector System", Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

6. Brown, B.F., & R.J. Goode, "Evaluating Mechanical and Corrosion Suitability of Materials", ASME Conference, ASME Paper No. 67-DE-7, May 15-18, 1967.

7. Bridges, R.M., "Structural Requirements of Undersea Electrical Cable Terminations", 7th Annual Marine Technology Society Conference, Washington, D.C., August,1971.

8. Berian, A.G., "Compatibility of Underwater Cables and Connectors", Oceans, 1976.

9. Busby, R.F., "Power Distribution" Manned Submersibles, Office of the Oceanographer of the Navy, 1976. Pages 338-368.

10. Bratt, A.R., "Evaluation of MIL-M-24041", Polyester Based Polyurethane Molding Compounds and Primers for Resistance to Long-Term Salt Water Immersion and Cyclic Hydrostatic

10. Continued

Pressure", Portsmouth Naval Shipyard Evaluation Report No. E71-95N/C, October, 1971.

11. Browm, B.F., "Corrosion in the Marine Environment", MTS 6th Annual Conference, Pages 1225-1231, June 24-July 1, 1970.

C1. Calhoun, F., "Submarine Cable System for the Florida Missile Test Range", Third Annual Wire and Cable Symposium, 1954, AD 656256.

2. Casarella, M.J. & J. Parsons, "Cable System Under Hydro-hydynamic Loading", <u>MTS Journal</u>, July-August, 1970.

3. Comer, J., "Glass-to-Metal Seals", <u>Electrical Manufacturing</u>, March, 1958.

4. "Corrosion and Corrosion Protection of Metals", MIL-HDBK-721 (MR) Military Standardization Handbook, November 1, 1965.

5. Carson, D.L. et.al., "Composite-Unit Accelerated Life Testing (CUALT) of Sonar Transducers", NOSC Document No. TR-516, Naval Oceans Systems Center, San Diego, CA 92152.

6. Carson, D.L. et.al., "Interim Report on Composite Unit - Accelerated Life Testing (CUALT) of Sonar Transducers", NOSC Technical Note 675, March, 1979. Naval Ocean Systems Center, San Diego, CA 92152.

D1. Dibble, W.H., "The Development of Arctic Rubber Insulations and Jackets", First Annual Wire and Cable Symposium, 1952.

2. Debbi, H., "How to Make Glass-to-Metal Seals - Part I - Matched Seals", Insulation, June, 1968.

3. Debbi, H., "How to Make Glass-to-Metal Seals - Part II, Mismatched Seals", Insulation, July,1968.

4. Dalton, R.H., "How to Design Glass-to-Metal Joints, Product Engineering, April 26, 1965.

5. DSSP Instruction 9020.2, "Guidelines for Corrosion Control", PMS-11/201/SH:PM of December 31, 1968.

E1. Edwards, F.L., & R.A. Patterson, "Pressure Balanced Electrical Hull Penetrators and External Cabling for DEEPSTAR 20,000", Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

2. Ehrlich, A., & J.W. Hayes, "Thermal and Hydrolytic Stability of Urethane Resins", 9th Electrical Insulation Conference (EIC), Boston, MA September 8-11, 1969.

3. Elmendorf, C.H. & B.C. Heezen, "Oceanographic Information for Engineering Submarine-Cable Systems", The Bell System Technical Journal, September, 1957.

4. Electric Boat Division CPG 1060, "Procedures for Wiring, Molding, Inspection and Testing Pressure-Proof Electrical Connectors for TRIDENT Submarines", April, 1977, Rev. "B".

5. Electric Boat Division CPG 1099, "Splicing Procedure for Neoprene and Polyurethane Jacketed Cables on TRIDENT Submarines", Electric Boat Division, April, 1977.

6. Electric Boat Division CPG 1326, "Procedures for Molding, Inspection and Testing Transducer Cable Glands for TRIDENT Submarines", Electric Boat Division, November, 1978.

7. Electric Boat Division CPG 1145, "Installation Procedures - TRIDENT Outboard Electrical Harnesses and Hull Penetrators", Electric Boat Division, dated December 30, 1977.

8. Electric Boat Division CPG 1096, "Procedure for Splicing Type 1PR-A20E Polyethylene Jacketed Cables on TRIDENT Submarines", Electric Boat Division, December, 1978, Rev. "B".

9. Electric Boat Division Procedure U 413-67-090, "Autec-Watertight Electrical Cable Harness Molding Manual", June 12, 1967.

F1. Fisk, C.D., & J.P , Hal "Electrical Connectors and Cables for Underwater vice", BENDIX Electrical Components Division, Sidne, NY, L-2025.

2. Field, N.H., "A Reliable Gland for Rubber Cables", Admiralty Research Laboratory, Teddington, England, April, 1969, DDC No. AD 857-371.

3. Forster, G.A., "Hermetic Sealing Terminals", WADC Technical Report 56-251, AD 107274, April 1956.

G1. Gahimer, F.H., & F.W. Nieske, "Navy Investigates Reversion Phenomena of Two Elastomers", Insulation, August, 1968.

2. Gahimer, F.H. & F. W. Nieske, "Hydrolytic Stability of Polyurethane and Polyacrylate Elastomers in Humid Environments", NAFI Report No. TR-1372, February 27, 1969.

3. Gahimer, F.H. & F.W. Nieske, "Properties of Commercial Polyurethane Rubber Encapsulating Compounds", NAFI Report No. TR-1032, October 15, 1967.

4. Gahimer F.H., & F.W. Nieske, "Reversion of Polyurethane and Polyacrylate Rubber Encapsulating Compounds in Humid Environments and Development of a Standard Reversion Test", NAFL Report No. TR-1201, April 15, 1968.

5. Griffin, W.R., "Reconstitution of Reverted Polyurethane Potting Compounds", AFML-TR-68-398, April, 1969.

11. Haworth, R.F., et al., "Final Report - Phase I Review, Design, Fabrication and Test Program for Deep Submergence Electrical Connectors and Penetrators", Electric Boat Division Report No. C 413-70-016 (C), 3 Volumes, May, 1970.

2. Haigh, K.R., "Instrumentation Interference in Submersibles," 6th Annual Marine Technology Society Meeting, Washington, D.C., June 29 - July 1, 1970.

3. Haworth, R.F., "Packaging Underwater Electrical/Electronic Components on Deep Submergence Vehicles," Insulation/Circuits, December 1970.

4. Haworth, R.F., "Design Study Report: Watertight Hermetically Sealed Electrical Connectors for Submarines", GD/EBDivision Report No. SPD 60-101, Page 60-194, Contract NObs 77007, October 31, 1960.

5. Haworth, R.F., "Electrical Cabling System for the STAR III Vehicle", ASME Conference, ASME Paper No. 66-WA/UNT-11, November 27 to December 1, 1966.

6. Haworth, R.F., & J. E. Regan, "Watertight Electrical Connector for Undersea Vehicles and Components", ASME Conference, ASME Paper No. 64-WA/UNT-10, November 29, to December 4, 1964.

7. Hunt, J.R., & M.D. Bellware, "Ocean Engineering Hardware Requires Copper-Nickel Alloys, The International Nickel Company, Inc.

8. "Handbook of Vehicle Electrical Penetrators, Connectors and Harnesses for Deep Ocean Applications", Naval Ship Engineering Center, Hyattsville, MD, July, 1971 AD 888281.

(Continued)

9. "Handbook of Pressure-Proof Electrical Harness and Termination Technology for Deep Ocean Applications", Naval Sea Systems Command, Washington, D.C., 20362, NAVSEA 03TH-74-010, August, 1974.

10. "Handbook of Electrical Cable Technology for Deep Ocean Applications", Naval Ship Systems Command, Washington, D.C., 20360, AD 877-774, November, 1970.

11. "Handbook of Submarine Antenna Improvement Program", NUSC No. 551, NUSC, New London, CT.

12. Hunt, J.R., & M.D., Bellware, "Ocean Engineering Hardware Requires Copper-Nickel- Alloys", International Nickel Company.

13. Hillis, F.M. "Aerospace Connectors Adapters for Hydrospace Applications", BENDIX Electrical Components Division, Sidney, NY, L-2004.

14. Hosom, D.S., "Oil Filled Electrical Cables External to Pressure Hull on DSV Alvin", Oceans, 1976.

15. Haworth, R.F., "Design Analysis of the Pressure-Proof Connector for the AN/SQS-56 Transducer", EBDivision Report No. U 443-78-091, December, 1978, (Contract No. N66001-77-C-0020).

16. Haworth, R.F., "Electrical Cable and Connector Design for the Hazeltine Corporation DT-308 ( ) Hydrophone", EB Division Report No. U 443-78-084, December, 1978 (Contract No. N66001-77-C-0220).

(Continued)

17. Haworth, R.F., "Electrical Cable and Connector Design for the Ametek-Straza TR-215 ( ) Sonar Projector", EBDivision Report No. U 443-78-036, December, 1978, Contract No. N66001-77-C-0020.

18. Hackman, D.J., & B. R. Lower, "Summary Report on a Study to Decrease Wire Breakage in Underwater Electrical Connectors", BATTELLE Memorial Institute, Columbus Laboratories, April 30, 1968.

19. Haigh, K.R., "Deep-Sea Cable-Gland System for Underwater Vehicles and Oceanographic Equipment", Proceedings, IEEE, Volume 115, No. 1, January, 1968.

20. Haworth, R.F., "Feasibility Study of Using Underwater Make and Break Electrical Connectors on the NR-1", EBDivision Report No.: U 443-78-079, December, 1978. Contract No.: N00024-78-C-7003, Task 192.

21. Haworth, R.F., & Miner, H.C., "Outboard Electrical/Electronic Cable Assemblies Used on SSB(N) Submarines", EBDivision Document No.: U 443-77-021, dated February 28, 1977.

22. Haworth, R.F. "Clamp Selection Considerations for Raploc Plug Molded Boat Seals" EB Division Document No. CPG 1426, April, 1980

23. Haworth, R.F. Pressure-Proof Electrical Connector Design Recommendations for the Raploc Program "EB Division Document No. CPG 1380, October, 1979.

I1. International Wire Products Corporation,"Flex Test Report - True Concentric Versus Unilay Stranded Wire," International Wire Products Corporation, Midland Park, New Jersey, 1962.

2. Ingham, F.H., "B.O.P. Subsea Electrical Connector - Application", Design and Test Program, Oceans, 1976.

J1. Jerome, R., & J. L. March, "Designers Guidelines for Selection and Use of Metallic Materials in Seawater Applications", GD/EBDivision Report, December 8, 1966.

2. Johnson, H.E., "Evaluation of Light-Weight Insulation Systems for Aerospace Wire", Sixth Annual Bureau of Naval Weapons Symposium on Advanced Techniques for Aircraft Electrical Systems, Washington, D.C., October 12-13, 1965.

K1. Kutzer, L.G., "Joining Ceramics and Glass-to-Metals", Material in Design Engineering, January, 1965.

2. Kitchin, D.W., & O.S. Pratt, "Jointing Polyethylene - Insulated Submarine Cables", IEEE Transactions, Volume 78, Pt IIIA, 1959.

3. Klonaris, O., "Underwater Connectors, Undersea Science and Technology Journal, June, 1970.

L1. Lebovits, A., "The Permeability and Swelling of Elastomers and Plastics at High Hydrostatic Pressures", Ocean Engineering, Volume 1, Pergamon Press, 1968.

2. Lenkey, J., III, "Underwater Cables for Instrumentation," Oceanology International, July/August, 1969.

3. Lenkey, J., III & W.W. Wyatt, "Polyethylene Bonding to Metal for Cable Penetration of Pressure Hulls and Communications Applications", 17th Annual Wire and Cable Symposium, Atlantic City, New Jersey, December 4-6, 1968.

4. Leute, F.A., "Urethanes Made Stable at Elevated Temperature and Humidity", Insulation, August, 1968.

5. LaQue, F.L., & H. H. Capson, "Corrosion Resistance of Metals and Alloys", Reinhold Publishing Corporation, New York, 1963.

6. Luca, V.A., Jr., & Schildkraut, A.L., "Electrolytic Erosion in Connector - Causes and Cures", 12th Annual Connector Symposium, Cherry Hill, New Jersey, October, 1979.

7. Lewis, T.L. "Cable Failures in the AN/BQS-15 Sonar System - Analysis of Failures in the Depression/Elevation drive-motor Power Cable and Recommendations for their Prevention" Naval Oceans Systems Center, San Diego, Co. Technical Report No. 627. June, 1980.

M1. Malootian, M.H., "The Effect of Water Immersion on Some Tensile-Shear Bonds", USL Technical Memo No. 2220-124-67, June, 1967.

2. Marriott, J.A., "Development of Adhesives for Salt Water Use", GD/EBDivision Report No. U 413-63-168, December 31, 1963.

3. MIL-C-915C (NAVY), "Cable, Cord and Wire, Electrical (Shipboard Use)".

4. MIL-W-16878, "Wire, Electrical, Insulated High Temperature".

5. MIL-M-24041 (SHIPS), "Molding and Potting Compound, Chemically Cured Polyurethane - (Polyether - Based)".

6. MIL-C-24217, "Connectors, Electrical, Deep Submergence", Submarine".

7. MIL-C-24231, "Connectors, Plugs, Receptacles, Adapters, Hull Inserts, and Hull Insert Plugs, Pressure-Proof, General Specification for".

8. Morris, L., "Organic Materials in Hydrospace Applications", Products Research Company, February 26, 1964.

9. Morrison, J.B., "An Investigation of Cable Seals", Applied Physics Laboratories, University of Washington, March 1, 1954.

(Continued)

10. Muraoka, J.A., "The Effects of Fouling by Deep-Ocean Marine Organisms", Undersea Technology, May, 1963.

11. Muraoka, J.A., "Effects of Marine Organisms", Machine Design, January 18, 1968.

12. Myers, J.J., "Handbook of Ocean and Underwater Engineering", McGraw Hill Book Company, New York, (Section 7, Corrosion, B.F. Brown, and "Materials for Marine Use", R.C. DeHart). 1969.

13. Miller, W.C., Jr., "A High- Reliability Oil-Filled Cable Harness Assembly for Use on an Underwater Blow-Out Preventer System", Offshore Technology Conference, Houston, Texas, May, 1977.

14. Military Specification MIL-C-17, "Cables, Radio Frequency, Flexible and Semi-rigid, General Specification for".

N1. NAVSHIPS 250-248,"O-Ring Service Manual", September, 1951.

2. Nelson, A.L., "Deep Sea Electrical Connectors and Feed-Through Insulators for Packaging Electronics", Material Electronic Packaging and Production Conference, Long Beach, California, June 9, 1965.

3. Nation, R.D., "Deep Submergence Cables, Connectors and Penetrators", Nortronics Division of Northrup Corporation, (DSSP Contract N00024-68-C-0217), February 21, 1967.

4. NAVSHIPS Drawing 815-1197255, "Epoxy Splice Kit for DSS-3 Cable and Plug Assembly Repair".

5. NAVSHIPS Drawing 815-1197343, "Watertight Splice for DSS-3 Cable; Wiring and Molding Procedures".

6. Nowatzki, John A., "Strength Member Design for Underwater Cables", 7th Annual Marine Technology Society Conference, Washington, D.C., August, 1971.

7. NAVSHIPS Drawing 815-1197170, "Connectors, Hermetically Sealed, 3, 4 and 5 No. 12 and 8 No. 16 Pins".

8. NAVSEA S9074-AA-MMO-010/DSV-3, 4, "Technical Manual - Fabrication, Installation, Maintenance and Repair, Outboard Cable Harness Assembly Turtle (DSV-3) Sea Cliff (DSV-4)", Prepared by the Mare Island Naval Shipyard, Naval Sea Systems Command, January, 1978.

9. NUSC Technical Document 5811, "Splicing Procedures for DSS-3 Cable", Naval Underwater Systems Center, New London Laboratory, April, 1977.

(Continued)

10. NAVSEA S9061-AA-MMA-010/SSBN-726 Class "Technical Manual - Maintenance and Repair Instructions for Pressure Hull Electrical Penetrators and Associated Outboard Components", Naval Sea Systems Command, October 3, 1977.

11. NAVSEA Drawing 815-1197377, Sheets 2 and 3, "Connector - Watertight - 5 Pin, Wiring and Molding Procedures for 1SWF-2 Cables".

12. NAVSEA Drawing 815-1197380, Sheets 1 and 2, "Plug for FSS-2 Cable-Wiring and Molding Procedure".

13. NAVSEA Drawing 815-1197381, "Connector, Electrical, Watertight, Submarine, Wiring and Molding Procedures (MIL-C-24217)".

14. NAVSHIPS 0962-022-2010, "Molding and Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables", Naval Ship Engineering Center, Washington, D.C., October 1, 1978.

15. NAVSHIPS Drawing NR-1-302-2663185, "Wiring, Molding, Testing, Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators", Naval Ship Engineering Center, Washington, D.C.

16. NAVMAT P-9290, "System Certification Procedures and Criteria Manual for Deep Submergence Systems", dated June, 1976.

(Continued)

17. NAVSEA Drawing 4551212, "Special Seal-Specification Control Drawing", (3 Sheets).

18. NUSC Drawing 02804001, "Three Pin Hull Fitting Plug Insta-lation Kit", (5 Sheets).

19. "Reliability Test Plan for RAPLOC WAA External Array Connectors/Cables", Prepared by Potomac Research Inc. for Naval Underwater Systems Center, New London, Ct., Contract N00140-79-D-6040, D.O. 0010.

01. O'Brien, D.G., "Pressure-Compensated Electro-Connective Systems for Outboard Usage on Deep Submersibles", IEEE Engineering in the Ocean Conference, San Diego, CA, 1971.

2. O'Brien, D.G., "Application of Glass-Hermetic Sealed Water-tight Electrical Connectors", D.G. O'Brien, Inc., Seabrook, N.H.

3. O'Brien, D.G., "An Update on Recommended Techniques for Terminating Underwater Electrical Connectors to Cables", 10th Annual Marine Technology Society Conference, 1974.

P1. Peters, H., "Bonding Polyethylene to Rubbers, Brass, and Brass Plated Metals", Bell Telephone Laboratories, October 15, 1957.

2. Penzias, W., & M.W. Goodman, "Underwater Electrical Connectors and Penetrators", Man Beneath the Sea, John Wiley & Soncs, Page 462-484.

3. Paradis, J., "Reference Manual on Interference Seals and Connectors and Undersea Electrical Applications", Naval Facilities Engineering Command, Washington, D.C., 20374, July, 1976, ADA-036841.

R1. Rauhut, H.W., "Pretreating Polyethylene for Optimum Structural-Adhesive Joints, - Theoretical Concepts and Surface Pretreatments", Adhesive Age, December 1968 and January 1970.

2. Reinhart, F.M., "Corrosion of Materials in Hydrospace - Part I, Irons, Steels, Cast Irons, and Steel Products", U.S.Naval Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-900, July, 1967.

3. Reinhart, F.M., "Corrosion of Materials in Hydrospace - Part II - Nickel Alloys", U.S.Naval Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-915, August, 1967.

4. Reinhart, F.M., "Corrosion of Materials in Hydrospace - Part IV - Copper and Copper Alloys", U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-961, April, 1968.

5. Reinhart, F.M., "Corrosion of Materials in Hydrospace - Part III - Titanium and Titanium Alloys," U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, Technical Memo N-921, September, 1967.

6. Reinhart, F.M., "Deep Ocean Corrosion", Geo-Marine Technology, September, 1965.

7. Reliability and Maintainability Handbook - NAVSHIPS 0900-002-3000, Chapter 12, "Failure Modes and Effects Analysis".

8. Richter, W.A., "Corrosion at the Bond Interface" Lord Kinetics.

S1. Sanford, H.L., et al, "Final Report - Watertight Deep Submergence Electrical Connectors and Hull Fitting for Submarines", EBDivision Report No. 413-65-185, Contract NObs 88518, October, 1965.

2. Sanford, H.L., & R.A. Cameron, "Design Study Report - Molding DSS-3 Cable Splices for External Use on Submarines", GD/EBDivision Report No. 413-62-211, December 12, 1962.

3. Saroyan, J.R., "Protective Coatings", Machine Design, January 18, 1968.

4. Smoley, E.M., "Design Criteria for Sealing Gasketed Joints", Machine Design, November 21, 1963.

5. Snoke, L.R., "Resistance of Organic Materials and Cable Structures to Marine Biological Attack", The Bell System Technical Jounral, September, 1957.

6. Spadone, D.M., "Meeting on Cables, Connectors and Penetrators for Deep Sea Vehicles", Deep Submergence Systems Project Office, Bethesda, MD, January 15-16, 1969.

7. Saunders, W., "Pressure-Compensated Cables", 8th Annual Marine Technology Society Conference, 1972.

8. Stasch, A., "Handbook on Hermetic Sealing", Amphenol Connector Division, Amphenol-Borg Electronics Corporation, Report No. 5-4, December 5, 1959.

9. Stasch, A., "The Hermetically Sealed Connector and Its Capabilities", Electronic Industries, May, 1964.

10. Susi, A., "General Specification for Connector, P-P Field Assembly, Multi-Conductor and Radia Frequency", NUSC Document No. C-342/9235-516, dated 10 March, 1980.

(Continued)

11. Sandwith, C.J. "Performance/Failure Analysis of Acoustic Array Connectors and Cables After 6-10 years of Service" Marine Technology Society and IEEE, Ocean 1978 Conference Proceedings, Wash. D.C. Sept 6-8, 1978.

12. Sandwith, C.J., Paradis, J.G., and Morrison, J.B. "Underwater Electrical Cable and Connector Seals: Same In-House Design Options, Commercial Options and Performance/Failure Analysis" MTS-IEEE, Ocean 1977 Conference Record, Vol 2, pp 29C-1 thru 29C-6, October 17-19, 1977.

T1. Thomson, J.L., "Packed Glands for High Pressure", Product Engineering, November 20, 1958.

2. Thym, G.C., & R.A. Swan, "Underwater Cable Connectors and Terminators for the Hydrostatic Pressures to 10,000 psi", 10th Annual Wire and Cable Symposium, Asbury Park, New Jersey, November, 1961.

3. Todd, G.F., "Cable Sheaths and Water Permeability", 8th Annual Wire and Cable Symposium, Asbury Park, New Jersey, December 1959, AD 656243.

4. Tuttle, J.D., "Underwater Electrical Integrity", 7th Annual Marine Technology Society Conference, Washington, D.C., August, 1971.

5. Tuthill, A.H., & C.M. Schillmoller,"Guidelines for Selection of Marine Materials", International Nickel Company, 1966.

AD-A111 931 GENERAL DYNAMICS GROTON CT ELECTRIC BOAT DIV F/G 11/1
HANDBOOK OF PRESSURE-PROOF CONNECTOR AND CABLE HARNESS DESIGN F--ETC(U)
DEC 81 R F HAWORTH N61339-80-C-0021

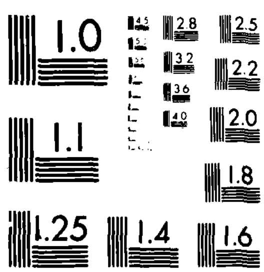
UNCLASSIFIED NRL-MR-4601 NL

8 OF 8

END
DATE
FILMED
4-82
DTIC

8 OF 8

AD A111931



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

(Continued)

6. Tuthill, A.H., & C.M. Schillmoller, "Guidelines for Selection of Marine Materials", The International Nickel Company, New York, 1966.

7. Thomas, J.F., "A Study of Cable, Connector and Penetrator Specifications", Naval Ship Research & Development Laboratory, Annapolis, MD ATD-14, 1969.

8. Timme, R.W., "Sonar Transducer Reliability Improvement Program FY-80 Second Quarter Report", NRL Memorandum Report 4196, NRL Underwater Sound Reference Detachment, Orlando, FL, 32856, April 1, 1980.

U1. Uhlig, H.H., "The Corrosion Handbook", John Wiley, New York, 1948.

2. USL Publication No. 948, "Handbook of Cable Splicing and Molding Procedures", U.S. Navy Underwater Sound Laboratory, New London, CT, August 1, 1968.

W1. Walsh, D.K., "Underwater Electrical Cables and Connectors Engineerered as a Single Component", Marine Technology Society Conference, June 1966.

2. Wolski, B., "NR-1 Special Test for Outboard Electrical Plug/Cable Assemblies and Junction Boxes", Two Volumes, GD/EBDivision Report No. 418-69-002, April 25, 1969.

3. Wolski, B., "NR-1 Special Test for Electrical Hull Fittings, Junction Boxes and Associated Cable Assemblies", Two Volumes, GD/EBDivision Report No. 418-68-010, October 22, 1968.

4. Wilson, J.V., "Sonar Cable and Connector Problems-FY-78 Strip Task C-1 Final Report", Civil Engineering Laboratory, Port Hueneme, California, TM No. 43-79-01, October, 1978.

5. Werth, D.A., "High Pressure Titanium Electrical Connectors", BENDIX Electrical Components Division, Sidney, New York, L-1097.

6. Wilson, J.V., "General Technology Review of Electrical/ Electro-Mechanical Cable Connectors in Ocean Systems", Naval Civil Engineering Laboratory, Port Hueneme, California, L43/JVW/1h, 1973.

7. Wilson, J.V., "Applying Wet Connectors", Ocean Industry, 10/78.

8. Wilson, J.V., "Coaxial Underwater Mateable Connectors - A New Technology for Seafloor Structure Applications", Civil Engineering Laboratory, Port Hueneme, CA 93043, Report No.: R875, dated September, 1979.

(Continued)

W9. Wilson, J.V., "Underwater Mateable Electromechanical Connectors for Power and Signal Cables", 8th Annual Offshore Technology Conference, May 3-6, 1976, Houston, TX, Paper No. OTC 2581.

10. Wilson, J.W.,& McCartney, J.F., "Development of an Underwater Mateable High-Power Cable Connectors, 6th Annual Offshore Technology Conference, May 6-8, 1974, Paper No. OTC, 1976.

1. Zuraw, E.A., "Polyethylene to Metal Bonding - A Literature Review - Phase I", Electric Boat Division Report No.: U 440-73-030, February 27, 1973 (Contract N00024-71-C-0311).

2. Zuraw, E.A., "Polyethylene to Metal Bonding - Evaluation of Potential Methods - Phase II", Electric Boat Division Report No.: U 440-73-112, November 15, 1973. (Contract N00024-71-C-0311).

3. Zuraw, E.A., "Elements of Bonding Polyethylene to K-Monel Metal for Underwater Electrical Applications - Phase III", Electric Boat Division Report No. U 440-75-039, April, 1975. (Contract N00024-71-C-0311).

4. Zuraw, E.A., "Bonding Polyethylene to K-Monel Metal", Electric Boat Division Report No. U 440-74-042, May 9, 1974.

5. Zuraw, E. A. "Elements of Polyethylene-Neoprene Cable Splicing" Electric Boat Division Report No. U 440-74-134, 20 Dec, 1974.

(BLANK)

APPENDIX A

GLOSSARY

For a better understanding of the terminology used in this Handbook, the following glossary is presented. Rather than compile one list of terms, the nomenclature is separated into five categories:

A-1 CONNECTOR PLUG

Conductor Barrel	-	The section of the contact which accomodates the conductor.
Banding Clamp (See Figure 2-15)	-	A banding device used to assist sealing the molded plug boot to the plug shell.
Contact (See Figure 2-2)	-	The conductive element in a connector which makes actual contact for the purpose of transferring electrical energy.
Contact Retainer Clip	-	A spring device surrounding the contact which locks the contact in the bore of the insulator.
Coupling Ring Lockwire	-	A wire used to secure the coupling ring against uncoupling.
Coupling Ring (See Figure 2-1)	-	A device fitted to the plug assembly which engages and disengages the plug to the receptacle.
Coupling	-	Same as above.
Coupling Ring Flange	-	The annular protrusion part of the plug shell against which the coupling ring bears as it is engaged with the receptacle.
Coupling Ring Shoulder	-	The innermost part of the coupling ring which bears on the coupling ring flange.

A-1 CONNECTOR PLUG

(Cont'd)

Thrust Washer (See Figure 2-4)	-	A thin annular bearing member fitted between the coupling ring and the molded cable boot seal which facilitates rotation of the coupling ring in the process of unmating the plug.
Dovetail Groove (See Figure 2-4)	-	The annular flange on the plug shell which the primary O-ring gasket fits and is retained.
Front Insulator (See Figure 2-5)	-	The dielectric body containing an arrangement of axial holes into which the contacts are fitted and retained.
Conductor Inspection Hole	-	A small hole near the base of the contact conductor barrel which allows visual assurance that the conductor is fully seated in the barrel following the crimping operation.
Insulator	-	A dielectric component of a connector which is used to insulate the pin and socket contacts.
Insulator Bore	-	The hole in the insulator into which the socket contact is assembled and retained.
Insulator Thrust Shoulder	-	A projecting surface in the front insulator which resists the axial load caused by the hydrostatic pressure acting at the rear face of the plug.

Molded Boot Seal (See Figure 2-7)	-	The elastomeric material molded onto the plug shell and the cable whose primary function is to provide a cable-to-connector seal against the seawater environment.
Plug (See Figure 2-10)	-	The male component of a connector set, the front part of which fits into the receptacle. The plug is usually that portion of the connector set which is affixed to the cable. The enclosed contacts are usually sockets.
Plug Shell (See Figure 2-9)	-	The body of the plug which houses and properly positions the insulator assembly and associated wiring.
Plug Sleeve	-	Same as above.
Polarizing Keyway (See Figure 6-4)	-	A slot in the plug designed to accommodate the mating receptacle key. It provides proper relative angular alignment of the mating members.
Protective Plug Cover	-	A non-pressure-proof cover fitted to a plug whose primary function is to protect against mechanical damage and contamination by dirt or other foreign objects.
Plug Cap	-	Same as above.
Pressure-Proof Plug Caps (See Figure 6-9)	-	A cover fitted to a plug whose primary function is to provide protection against full submergence seawater pressure.

Sealing Plug	-	A cover fitted to a plug whose primary function is to provide protection against full submergence seawater pressures.
Sleeving	-	Tubular plastic insulation material fitted over socket contacts in the spring clip area to prevent the potting compound from entering the contact cavity. Also electrical insulation material used in solder and crimp terminations.
Polarizing Key (See Figure 6-4)	-	A projection inside the plug or receptacle which engages a corresponding keyway. Together they provide proper relative angular alignment about the axis of the mating connector set.
Rear Insulator (See Figure 2-5)	-	A dielectric bushing which also serves as a spacer to hold the front insulator against the thrust shoulder of the plug shell.
Retaining Ring (See Figure 2-1)	-	A cylindrical spring device located in a groove which retains the front and rear plug insulators in place.
O-Rings (See Figure 2-1)	-	Cylindrical elastomeric gaskets having a circular cross-section used to seal the plug to the receptacle.
Socket Contact (See Figure 2-1)	-	A contact having a female engagement end which accepts a male pin contact.

A-1 CONNECTOR PLUG

(Cont'd)

Spanner Wrench Holes	-	The holes into which a pin type spanner wrench fits to tighten or loosen the plug coupling ring.
Spanner Wrench Slots	-	The slots into which the hook type spanner wrench fits to tighten or loosen the plug coupling ring.
Contact Solder Pot	-	A small cuplike vessel at the rear extremity of the contact designed to accommodate the stripped end of an insulated conductor and retain the mass of fused solder used in joining the conductor to the contact.
Right Angle Plug	-	A plug connector having the cable wired and molded at (90^{o}) right angle to the axis of the plug shell.
Straight Plug	-	A plug connector having the cable wired and molded on the same axis of the plug shell.
Gasket (See Figure 2-6)	-	A device used to seal a MIL-C-24231 plug connector to a receptacle connector. An O-ring type gasket is bonded to a Monel washer.
Contact Spring	-	The spring placed inside the socket contact to force the pin contact into position of positive intimate contact.

A-2 CONNECTOR RECEPTACLE

Contact Gasket (See Figure 2-4)	-	A cured elastomeric dielectric sealant poured into the base of the receptacle cavity.
Face Seal	-	Same as above.
Coupling Ring Thread	-	The external thread on the receptacle which is engaged by the plug coupling ring for the purpose of mating and unmating the plug and receptacle.
Glass Bead	-	The cylindrical glass preform as it exists prior to the contact glass sealing (fusing) operation.
Hermetic Glass Seal (See Figure 2-5)	-	The compression glass sealed bead which seals and insulates the pin contacts to the receptacle web section.
Locknut (See Figure 7-5)	-	An internally threaded ring which screws into the rear portion of a locknut type receptacle to secure the receptacle to a housing.
Pin Contact (See Figure 2-1)	-	A male contact having an engagement end that enters into a female socket contact.
Protective Receptacle Cover	-	A non-pressure proof cover fitted to a receptacle whose primary function is to protect against mechanical damage and contamination by dirt or other foreign objects.

A-2 CONNECTOR RECEPTACLE

(Cont'd)

(Receptacle) Cap	-	A non-pressure proof cover fitted to a receptacle whose primary function is to protect against mechanical damage and contamination by dirt or other foreign objects.
Pressure-Proof Receptacle Cap (See Figure 6-9)	-	A cover fitted to a receptacle whose primary function is to provide protection against full submergence seawater pressures.
Polarizing Key (See Figure 6-4)	-	A projection inside the receptacle which engages a corresponding plug keyway. Together they provide proper relative angular alignment of the mating members.
Polarizing Keyway (See Figure 6-4)	-	A slot in the plug or receptacle designed to accommodate the mating plug keyway. It provides proper relative angular alignment of the mating members.
Receptacle (See Figure 2-1)	-	The female component of the connector set, the cavity of which accommodates the plug shell. The receptacle is normally the fixed member of the connector set. The enclosed contacts are visually the pin type.

A-2 CONNECTOR RECEPTACLE

(Cont'd)

Receptacle Seal Face	-	The surface of the receptacle which provides a seal surface for a plug mounted sealing gasket.
Receptacle Seal Ring	-	An annular ring which fits between the locknut and the housing and provides a seal surface for the receptacle-housing secondary O-ring gasket.
Receptacle Shell (See Figure 2-1)	-	The main body of the receptacle which houses and protects the contacts.
Receptacle Body (See Figure 2-1)	-	Same as above.
Receptacle Style (See Figure 7-5)	-	The general configuration of a receptacle which better suits it to one type of mounting to a housing than another. The various styles are: welded; flanged welded; in line; mid-flanged bolted; end flange bolted; locknut and union.
Welded Receptacle (See Figure 7-1)	-	A receptacle which is affixed to a housing by welding at the rear of the receptacle.
Flanged Welded Receptacle (See Figure 7-1)	-	A receptacle having a flange at the mid section of the receptacle body to provide for welding the flange to the housing; thus shortening the exposed portion of the receptacle from the housing wall.

A-2 CONNECTOR RECEPTACLE

(Cont'd)

In Line Receptacle (See Figure 7-6)	-	A receptacle wired and molded to a cable.
Mid-Flange Bolted Receptacle	-	A receptacle having a flange at the mid section of the receptacle body to provide for O-ring sealing and bolting the receptacle to the housing.
End Flanged Bolted Receptacle (See Figure 7-5)	-	A receptacle having a flange at the rear of the receptacle body to provide for O-ring sealing and bolting the receptacle to the housing.
Locknut Receptacle (See Figure 7-5)	-	A receptacle having an O-ring sealing flanged at the front of the receptacle and threads at the rear end to allow fastening the receptacle to the housing with a locknut.
Union Receptacle	-	A receptacle having female cavities on both ends of the receptacle to provide for mating plug connectors to each end of the receptacle.
Spacer (See Figure 7-5)	-	A cylindrical ring used in conjunction with a locknut receptacle to allow for variations in the housing wall thickness.

A-2 CONNECTOR RECEPTACLE

(Cont'd)

Cap Shell	-	The cover portion of the pressure-proof receptacle cap assembly.
Locknut Union Receptacle	-	A receptacle having female cavities on both ends of the receptacle to provide for mating plug connectors to each end of the receptacle. The receptacle is retained in the housing with a locknut.
Secondary Receptacle Seal (See Figure 7-5)	-	The redundant O-ring gasket located in the receptacle which is normally not in contact with seawater and only sees service should the primary O-ring gasket fail or inadvertently not be installed.
Pin (See Figure 2-1)	-	A polarizing pin welded to the receptacle body on MIL-C-24231 receptacles to polarize the receptacle to the molded insert assembly.
Nylon Insert (See Figure 2-1)	-	A nylon pellet located in the thread area of MIL-C-24231 receptacles to lock the plug coupling to the receptacle.
Molded Insert Assembly (See Figure 2-1)	-	A cylindrical epoxy housing used in MIL-C-24231 receptacles to seal, locate, and insulate the pin contacts to the receptacle body. The insert has a groove to house an O-ring gasket which seals the insert to the body.

A-2 CONNECTOR RECEPTACLE

(Cont'd)

Retaining Ring (See Figure 2-1)	-	A cylindrical spring device located in a groove in the receptacle body which retains the molded insert assembly in the receptacle.
O-Ring Gaskets (See Figure 2-1)	-	Cylindrical elastomeric gaskets having a circular cross-section which are used to seal the plug to the receptacle and the receptacle body to the molded insert assembly.
Tailpiece (See Figure 7-6)	-	An adapter threaded to the rear portion of an in line receptacle to increase its overall length and thus provide a large bonding surface.
Receptacle Web (See Figure 2-4)	-	The portion of the MIL-C-24217 receptacle shell which retains and seals the pin contacts. The web is integral with the receptacle shell and is designed to withstand full submergence seawater pressure.

A-3 HULL PENETRATOR

Hull Penetrator (See Figure 5-1)	-	A pressure-proof device which is designed to allow the passage of electrical circuits through the pressure hull of a submarine or vehicle. The penetrator seals and insulates the conductors as they pass through the hull.
Body (See Figure 5-2)	-	The cylindrical pressure-proof housing to which connectors are mounted on the outboard side of the body. A connector assembly may also be mounted on the inboard side. The body is usually O-ring sealed to a hull insert and retained with a nut located on the inboard side of the hull.
Designation Plate (See Figure 5-1)	-	A hull penetrator identification plate which denotes receptacle position numbers, penetrator hole number, and specification number.
Nut (See Figure 5-2)	-	A large metal nut located on the inboard side of the penetrator body to retain the penetrator in the pressure hull.
Washer (See Figure 5-2)	-	A cylindrical device located between the nut and the hull insert to provide a sealing surface for the secondary O-ring gasket which seals the penetrator to the hull insert.

A-3 HULL PENETRATOR

(Cont'd)

Retaining Ring (See Figure 5-2)	-	A cylindrical spring device located in a groove on the inboard side of the hull penetrator to retain the nut in the penetrator body.
Packing (See Figure 5-2)	-	A cylindrical elastomeric seal containing holes through which insulated conductors or cables pass through to provide a secondary conductor (cable) seal.
Retainer Plates (See Figure 5-2)	-	Discs situated on both inboard and outboard faces of a packing which tends to distribute the thrust of the gland nut evenly over the packing to provide conductor sealing. The plates present packing extrusion into cavities which would allow seal loss. The inboard disc house two polarizing pins to prevent disc rotation at assembly.
Gland Nut (See Figure 5-2)	-	A threaded member which, when tightened, compresses a rubber packing to provide a conductor (cable) seal.
Hull Insert (See Figure 5-2)	-	A structural member used to reinforce the hull plate in the immediate vicinity of a hole through the hull. It is most often a thick walled cylinder welded into the hole of the submarine pressure hull.

A-3 HULL PENETRATOR

(Cont'd)

Dowel Pin (See Figure 5-3)	-	Pins pressed into the outboard side of the hull insert face to prevent penetrator rotation when tightening the inboard nut. The pins also polarize the penetrator to the hull insert.
O-Ring Gasket (See Figure 5-1)	-	Cylindrical elastomeric gaskets having a circular cross-section which are used to seal the penetrator body to the hull insert on the outboard and inboard sides of the pressure hull. The gaskets are located in triangular shaped O-ring seats which create a "crush seal" gasket.
Internal Wiring (See Figure 5-2)	-	The group of insulated conductors which run from the molded receptacle inserts through the packing located on the inboard side of the penetrator.
Single Connector Hull Penetrator (See Figure 5-2)	-	A hull penetrator design which houses only one pressure-proof receptacle outboard side of the penetrator body.
Multi-Connector Hull Penetrator (See Figure 5-1)	-	A hull penetrator design which houses many pressure-proof receptacles in a turret fashion around the outboard side of the penetrator body.

Abrasion Resistance	-	A measure of the ability of a wire, wire covering or material to resist surface wear or damage by mechanical means.
Aging	-	The change in properties of a material with time, under specific conditions.
American Wire Gauge (AWG)	-	The standard system used for designating wire size.
Ampacity	-	The maximum current a conductor can carry without heating beyond a safe limit.
Attenuation	-	Power loss in an electrical system. Attenuation of a transmission line is generally expressed in db per unit length, usually 100 feet.
Binder	-	Helically applied tape or thread used for holding assembled cable components in place until additional manufacturing operations are performed.
Braid Angle	-	The angle between the axis of the cable and the axis of any one member or strand of the braid (also known as angle of advance).
Breakdown Voltage	-	The voltage at which the insulation between two conductors will break down.

A-4 CABLE

(Cont'd)

Bunched Stranding	-	Term applied to a group of strands twisted together in a random manner in the same direction in one operation without regard to geometric arrangement of specific strands (see text on Conductors).
Cabling	-	The method by which a group of insulated conductors is mechanically assembled (or twisted together).
Caged Armor	-	Armor wires within a jacket often used in submarine cables.
Capactitive Coupling	-	Transfer of energy between two or more circuits, through the effect of the capacitance mutual to the circuits.
Carrier	-	The basic woven element of a braid consisting of one or more ends (strands) which create the interlaced effect.
Characteristic Impedance	-	Characteristic impedance of a uniform line is the ratio of an applied potential difference to the resultant current at the point where the potential difference is applied, when the line is much larger than a wavelength.

Circular Mil - A unit of area equal to the area of a circle whose diameter is 1 mil (0.001 inch); equal to square mil x 0.78540. Used chiefly in specifying cross-sectional areas of round conductors.

Cold Flow - Permanent deformation of material due to mechanical force or pressure (not due to heat softening).

Color Code - A color system for wire or circuit identification by use of solid colors, tracers, braids, or surface printing.

Concentric Strand - A strand that consists of a central wire of core surrounded by one or more layers of helically layed wires.

Concentricity - In a wire or cable, the management of the location of the center of the conductor with respect to the geometric center of the circular insulation.

Conductivity - The ability of a material to allow electrons to flow, measured by the current per unit of voltage applied. It is the reciprocal of resistivity.

Continuous Vulcanization (CV)	-	After a rubber of rubberlike compound is extruded onto a conductor, the wire is then passed into a vulcanizing chamber where the insulation or jacket is continuously vulcanized under high-temperature control.
Control Cable	-	A cable used for remote control operation of any type of electrical power equipment.
Copper-Covered Steel Wire	-	A type of high-strength conductor. (See text on Conductors).
Core	-	In cables, a term used to express a component or assembly of components over which other materials are applied, such as shield, jacket, sheath, or armor.
Corona	-	The ionization of gases about a conductor that results when the potential gradient reaches a certain value.
Corona Resistance	-	The time that insulation will withstand a specified level of field-intensified ionization that does not result in the immediate complete breakdown of the insulation.
Creepage	-	Electrical leakage distance on a solid dielectric surface.

Crosstalk	-	Signal interference between nearby conductors caused by the pick-up of stray energy.
Cure	-	To change the physical properties of a material by chemical reaction, by the action of heat and catalysts, alone or in combination, with or without pressure.
Current-Carrying Capacity	-	The maximum current a conductor can carry without heating beyond a safe limit. (See Ampacity)
Cut-Through Resistance	-	Ability of a material to withstand penetration by a solid object.
Decibel (db)	-	The decibel is a dimensionless unit for expressing the ratio of two values of power or voltage.
Delamination	-	The separation of layers in a laminate through failure of the bond or adhesive.
Dielectric	-	An electric insulating (non-conducting) medium.
Dielectric Absorption	-	A characteristic of dielectrics that determines the amount of time it takes a capacitor to deliver the total amount of its stored energy.

A-4 CABLE

(Cont'd)

Dielectric Breakdown	-	Any change in the properties of a dielectric that causes it to become conductive.
Dielectric Constant	-	Also called permittivity. That property of a dielectric which determines the amount of electrostatic energy that can be stored by the material when a given voltage is applied to it. Actually, the ratio of the capacitor using the dielectric to the capacitance of an identical capacitor using a vacuum as dielectric.
Direct Coupling	-	Direct coupling is the association of two or more circuits by means of self-inductance, capacitance, resistance, or a combination of these which is common to the circuits.
Dielectric Loss	-	The power dissipated in a dielectric as the result of friction produced by molecular motion when an alternating electric field is applied.
Dielectric Phase Angle	-	The angular difference in phase between the sinusoidal alternating potential difference applied to a dielectric and the component of the resulting alternating current having the same period as the potential difference.

A-4 CABLE

(Cont'd)

Dielectric Power Factor	-	The cosine of the dielectric phase angle.
Dielectric Strength	-	The voltage which an insulating material can withstand before breakdown occurs, usually expressed as a voltage gradient (such as volts per mil.).
Dielectric Test (Proof Voltage)	-	Tests which consist of the application of a voltage higher than the rated voltage for a specified time for the purpose of determining the adequacy against breakdown of insulating materials and spacings under normal conditions.
Double-Faced Tape	-	Fabric tape finished on both sides with a rubber or synthetic compound.
Drain Wire	-	In a cable, an uninsulated wire laid over the component or components and used as a ground connection.
Eccentricity	-	A measure of the center of a conductor's location with respect to the circular cross-section of the insulation. Expressed as a percentage of center displacement of one circle within the other.

(Cont'd)

Elastomer	-	A material which under tension stress at room temperature, elongates to at least twice its length and returns to its original length upon release of the tension stress.
Elongation	-	The fractional increase in length of a material stressed in tension.
Extrusion	-	Method of forcing plastic, rubber, or elastomer material through an orifice in continuous fashion to apply insulation or jacketing to a conductor or cable.
Fatigue Resistance	-	Susceptibility to breakage of conductors due to cyclical flexing.
Filled Tape	-	Fabric tape which has been thoroughly filled with a rubber or synthetic compound, but not necessarily finished on either side with this compound.
Filler	-	Materials used in multi-conductor cables to occupy the interstices formed by the assembled conductors. Also, a substance, often inert, added to a plastic to improve properties and/or decrease cost.

A-4 CABLE

(Cont'd)

Film	-	Sheeting having a nominal thickness not greater than 0.010 inch.
Flame Resistance	-	Ability of the material to extinguish flame once the source of heat is removed.
Flex Life	-	Number of cycles of repeated flexing that a material will withstand before failure.
Flexural Strength	-	The strength of a material in bending.
Free Flooding Cable	-	A cable in which the insulated conductors are exposed to the surrounding medium.
Glass Fibers	-	Used in yarn servings and braids and as strength members. High tensile strength, non-flammability, flexibility, and resistance to moisture and high temperatures are characteristic of glass fibers.
Heat Endurance	-	The length of time that a material can withstand heat aging before failing a specific physical test.

Heat Seal	-	A method of sealing a tape wrap insulation or jacket by means of thermal fusion.
Hygroscopic	-	Tending to absorb moisture.
Impact Strength Test	-	Test for ascertaining the punishment a cable can withstand without physical or electrical breakdown, by impacting with a given weight, dropped a given distance, in a controlled environment.
Impedance	-	The total opposition offered by a circuit, cable, or component to alternating current. It includes both resistance and reactance and is generally expressed in ohms.
Impregnate	-	To fill the voids and interstices of a material with a compound.
Inductive Coupling	-	Transfer of energy between two or more circuits through the effect of the inductance mutual to the circuits.
Insulation	-	A material having good dielectric properties which is used to separate close electrical components, such as cable conductors and circuit components.

Insulation Resistance	-	The resistance offered by the insulation of a conductor to the current resulting from an impressed direct voltage.
Interference	-	Disturbances of an electrical or electromagnetic nature that introduce undesirable responses into other electronic equipment.
Ionization	-	Generally, the dissociation of an atom or molecule into positive or negative ions or electrons. Restrictively the state of an insulator such that it facilitates the passage of current due to the presence of charged particles usually induced artificially.
Ionization Voltage	-	The potential at which a material ionizes; the potential at which an atom gives up an electron.
Irradiation	-	The exposure of an insulation material to high-energy radiation emissions for the purpose of favorably altering the molecular structure.

A-4 CABLE

(Cont'd)

Jacket - A continuous rubber or synthetic covering, sometimes fabric reinforced, over the insulation, core, or sheath of a cable. An outer jacket is sometimes referred to as a sheath.

Knuckling - A kinking, as a conductor subjected to column loading.

Lay - Pertaining to wire and cable, the axial distance required for one cabled conductor or conductor strand to complete one revolution about the axis around which it is cabled.

Lay Wrap - Tape wrapped around an object in an overlapping condition.

Longitudinal Wrap (Cigarette Wrap) - Tape applied longitudinally, with the axis of the core being covered as opposed to a helical tape-wrapped core.

Marker Tape - A tape laid longitudinally within a cable bearing printed information, such as the manufacturer's name and the specification to which the cable is made.

Marker Threads - A colored thread or combination of colored threads, layed parallel and adjacent to the strands of an insulated conductor which identifies the wire manufacturer and sometimes the specification to which the wire is made.

Megger - A meter used for making insulation resistance measurements at selected D.C. voltages. (Usually 50 or 500 volts DC.)

Migration of Plasticizer - Loss of plasticizer from an elastomeric plastic compound with subsequent absorption by an adjacent medium of lower plasticizer concentration.

MIL - 0.001 inch (1/1000 inch), one 1000th of an inch. A unit used in measuring diameter of wire or thickness of an insulation over a conductor.

Moisture Absorption - Generally, the amount of moisture in percentage that an insulation or jacket will absorb under specified conditions.

Moisture Resistance - The ability of a material to resist absorbing moisture from the air or when immersed in water.

Oil Filled Cable - Pressure-compensated group of insulated electric conductors contained within a jacket.

Ozone - An oxidizing agent. An allotropic form of oxygen, usually formed by a silent electric discharge in air.

A-4 CABLE

(Cont'd)

Pan Cured - Method of vulcanizing. Coils of unvulcanized insulated wire are coiled in pans and vulcanized under pressure with live steam.

Percent Conductivity - Conductivity of a material expressed as a percentage of that of copper.

Permeability - (1) The passage of diffusion (or rate of passage) of a gas, vapor, liquid, or solid through a barrier without physically or chemically affecting it.

(2) A measure of how much better a given material is than air as a path for magnetic lines of force. The permeability of air is assumed as one. Permeability is the magnetic induction B in gauss divided by the magnetizing force H in oersteds.

Picks Per Inch - The number of times the carriers in a braid cross over each other in the same direction along the longitudinal axis for each inch of length.

Plastic Deformation - Change in dimensions of an object under load that is not recovered when the load is removed.

Plasticizer	-	Chemical agent added to plastics to make them softer and more flexible.
Pressure Compensating Fluid	-	A liquid used to fill enclosures to protect components from deep sea environment.
Primary Insulation	-	A non-conductive material, usually the first layer over a current-carrying conductor, whose prime function is to act as an electrical barrier for the applied potential.
QUAD	-	A four conductor grouping, normally twisted, within a cable.
Reinforcement	-	A material used to reinforce, strengthen, or give dimensional stability to another material such as the braid portion of a jacket constructed in layers.
Rubber	-	An elastomer capable of rapid elastic recovery. Specifically, natural rubber, the standard of comparison for elastomers.
Secondary Insulation	-	A non-conductive material whose prime functions are to protect the conductor against abrasion and provide a second electrical barrier. Placed over the primary insulation.

A-4 CABLE

(Cont'd)

Semi-Conducting Jacket	-	A jacket having a sufficiently low resistance so that its outer surface can be kept at substantially ground potential by a grounded conductor in contact with it at frequent intervals.
Separator	-	A layer of insulating material such as textile, paper, Mylar, etc, which is placed between a conductor and its dielectric, between a cable jacket and the components it covers, or between various components of a multi-conductor cable. It can be utilized to improve stripping qualities and/or flexibility, or can offer additional mechanical or electrical protection to the components it separates. It also isolates incompatible cable materials.
Serving	-	A wrapping applied over the core of a cable or over a wire. Servings may be in the form of filaments, wires, fibers, yarn, tape, etc. "Served Wire Shield": Helically wound wires used to shield cables.
Sheath	-	A covering over a cable to provide mechanical protection and/or improve performance (see Jacket).
Sleeving	-	A braided, knitted, or woven tube.

A-4 CABLE

(Cont'd)

Shelf Life	-	Length of storage time under specified conditions that a material retains its usability.
Shield	-	A layer, usually metallic, placed around an insulated conductor or group of conductors to prevent electrostatic or electromagnetic interference between the enclosed wires and external fields.
Shield Coverage	-	The physical area of a circuit or cable actually covered by shielding material, expressed in percent.
Shield Effectiveness	-	The relative ability of a shield to inhibit the transfer of energy between electrical/electronic circuits. Not to be used interchangeably with the term "shield percentage coverage".
Single-Faced	-	Fabric tape finished on one side with a rubber or synthetic compound.
Solid Conductor	-	A conductor consisting of a single wire.
Stabilizer	-	An ingredient used in some plastics, to maintain physical and chemical properties throughout processing and service life.
Stranded Conductor	-	A conductor composed of a group of wires.

A-4 CABLE

(Cont'd)

Submarine Cable	-	Cable used underwater from one point to another for power or communication. Cable used outboard on Navy underwater vehicles.
Surface Leakage	-	The passage of current over the boundary surfaces of an insulator as distinguished from passage through its volume.
Tape	-	A relatively narrow, woven or cut, strip of fabric, paper, or film material.
Tear Strength	-	The force requird to initiate or continue a tear in a material under specified conditions.
Tensile Strength	-	The pulling stress required to break a given specimen.
Temperature Rating	-	The maximum temperature at which the insulating and jacket materials may be used in continuous operation without loss of its basic properties.
Thermal Expansion (Coefficient of)	-	The fractional change in length (sometimes volume) of a material for a unit change in temperature.
Thermal Shock	-	The resulting characteristics when a material is subjected to rapid and wide-range changes in temperature in an effort to discover its ability to withstand heat and cold.

Thermoplastic	-	A classification of resin that can be readily softened and resoftened by repeated heating.
Thermosetting	-	A classification of resin cured by chemical reaction when heated, and when cured, cannot be resoftened by heating.
Tubing	-	Extruded non-supported plastic or elastomer materials.
Twisted Pair	-	Two small insulated conductors twisted together, but having no common covering.
Unidirectional Concentric Stranding	-	A stranding where each successive layer has a different lay length, thereby retaining a circular form without migration of strands from one layer to another.
Unidirectional Stranding	-	A term denoting that in a stranded conductor all layers have the same direction of lay.

A-4 CABLE

(Cont'd)

Velocity of Propagation	-	Applied to coaxial cables, velocity of propagation is the ratio of the dielectric constant of air to the square root of the dielectric constant of the insulator. It indicates the transmission speed of an electrical signal down a length as compared to speed in free space.
Voltage Stress	-	That stress found within a material when it is subjected to an electrical charge.
Vulcanization	-	A chemical reaction in which the physical properties of an elastomer are changed by reacting it with sulfur or other cross-linking agents.
Wall Thickness	-	A term used to express the thickness of a layer of applied insulation of jacket.
Water Absorption	-	Ratio of the weight of water absorbed by a material to the weight of the dry material.
Waterblocked Cable	-	A cable constructed with no internal voids to prevent any longitudinal water passage under a given pressure.
Wire Gauge	-	A system of numerical designations of wire sizes. (e.g., American Wire Gauge, (AWG)).

A-5 CABLE HARNESS

Cable Assembly - (See Harness).

Cable - A grouping of insulated conductors usually in a circular cross-section in which the insulated conductors are enclosed by a jacket.

Cable Bend Radius - The minimum allowable radius of the circular arc into which a cable can be bent without causing undue stress on the internal members.

Conductor - An element, usually metallic, which easily conveys electrical current. Conventional conductors in cables or insulated wire may be of solid or stranded construction.

Conductor Size - Refers to the cross-sectional area of a conductor which is computed in circular mils and assigned a size number according to the American Wire Gauge (AWG) Standard.

Core - The part of an insulated cable enclosed by the jacket.

(Cont'd)

Crimp	-	Method of joining a contact or splice connector and conductor by means of systematical deformation of the contact or connector using special tools. The joint is formed by indentations on the outer wall of the contact, which forces its inner walls in intimate contact with the bare conductor.
End Seal	-	Is the deliberate blocking of an open cable end to create a pressure-proof barrier. This is usually an adjunct to hydrostatic testing of a connector molded to the cable and is done to prevent water from entering the cable.
Harness	-	Is a finished cable assembly complete with molded connectors on each end of the cable.
Insulation	-	A dielectric material, either rigid, semi-rigid or flexible, that electrically isolates one conductive element from another.
Lay	-	The axial length of one turn of a helix; used to describe the arrangement of conductor stranding or insulated conductors in a multi-conductor cable.

Molded Boot	-	The molded or vulcanized member of a harness forming the seal between the electrical cable and the connector or component.
Non-Hosing	-	A term applied to cables which contain filler materials in the conductor stranding and in the insulated conductor interstices to form a water barrier.
Pigtail	-	A short length of insulated wire extending from a component. Also applied to fine stranded, extra flexible lead wire for grounding or "jumpering".
Serving	-	A wrapping over the insulated conductors of a cable core for retention of the core's shape. The serving can be a tape, thread, or yarn.
Shield	-	A metallic barrier placed over or around an insulated conductor or conductors to reduce interference from external electrostatic fields. The shield can range from braided wire to a solid foil or rigid tube. The shielding effectiveness varies in proportion to the extent of coverage.

Splice	-	Designates the joining of corresponding insulated conductors in a cable using splice connectors of the crimp or solder type. The splice may or may not require covering with a molded, pressure-proof rubber boot.
Strain Relief	-	Is an integral or separate member attached to a component and cable at a critical flex point which prevents or reduces the amount of deformation and consequent stress imparted to the cable.
Stranded Conductor	-	A medium for transmitting electrical current. Stranded conductors are composed of multiple solid conductors of smaller gage twisted together to form a single conductor.

(BLANK)

APPENDIX B

LIST OF TABLES

TABLE B-1

Pertinent Military Test Specifications

No.	Description	Specification
1	Test methods for electronic and electrical component parts	MIL-STD-202
2	Test methods for electrical connectors	MIL-STD-1344
3	Standard general requirements for electronic equipment	MIL-STD-454
4	Methods of testing plastics	FED-STD-406
5	Metal test method	FED TEST METHOD 151
6	Calibration; system requirement	MIL-C-45662
7	Surface roughness, waviness, and lay	MIL-STD-10
8	Plastics, organic, general specification, test methods	L-P-406
9	Rubber, sampling and testing	FED TEST METHOD 601
10	Mechanical vibrations of shipboard equipment	MIL-STD-167
11	Shock tests, HI (high impact) shipboard machinery equipment and systems, requirements for	MIL-S-901
12	Non-destructive testing requirements for metals	MIL-STD-271
13	Environmental test methods	MIL-STD-810

TABLE B-2

Maximum Conductor Current Rating[2]

Wire Size (awg)	Amperes[1]
22	9
20	11
18	16
16	22
14	32
12	41
8	55
6	73
4	101
2	135
0	245
00	283
000	328
0000	380

NOTES:

(1) Single conductor in free air, continuous loading.

(2) Conditions are established under a maximum ambient temperature of 135°F and a maximum conductor temperature of 212°F.

TABLE B-3

Fractions Of An Inch With Metric Equivalent

Fractions Of An Inch	Decimals On An Inch	Milli-Meters	Fractions Of An Inch	Decimals Of An Inch	Milli-Meters
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6857	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15.32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700		1.0000	25.400

TABLE B-4

Unit Prefixes

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10	deka	da
0.1 = 10^{-1}	deci	d
0 01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

TABLE B-5

Nomenclature Of Frequency Bands

Band Number (1)	Frequency Range	Metric Subdivision	Adjectival Description	
2	30 to 300 hertz	Megametric waves	ELF	Extremely low frequency
3	300 to 3000 hertz	-	VF	Voice frequency
4	3 to 30 kilohertz	Myriametric waves	VLF	Very-low frequency
5	30 to 300 kilohertz	Kilometric waves	LF	Low frequency
6	300 to 3000 kilohertz	Hectometric waves	MF	Medium frequency
7	3 to 30 megahertz	Decametric waves	HF	High frequency
8	30 to 300 megahertz	Metric waves	VHF	Very-high frequency
9	300 to 3000 megahertz	Decimetric waves	UHF	Ultra-high frequency
10	3 to 30 gigahertz	Centimetric waves	SHF	Super-high frequency
11	30 to 300 gigahertz	Milli-metric waves	EHF	Extremely high frequency
12	300 to 3000 gigahertz OR 3 terahertz	Decimillimetric waves	-	

NOTES:

(1) "Band Number N" extends from 0.3 x 10^N to 3 x 10^N hertz. The upper limit is included in each band; the lower limit is excluded.

TABLE B-6

Deep Submergence Tables

FEET	0	100	200	300	400	500	600	700	800	900
Fathoms	0	16.7	33.3	50.0	66.7	83.3	100.0	116.7	133.3	150.0
Meters	0	30.5	61.0	91.4	121.9	152.4	182.9	213.4	243.8	274.3
Pressure (pascals x 10^4)	0	30.6	61.4	92.1	122.9	153.8	184.8	215.7	246.8	277.9
Pressure (psi)	0	44.4	89.0	133.6	178.3	223.1	268.0	312.9	358.0	403.1

FEET	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Fathoms	166.7	183.3	200.0	216.7	233.3	250.0	266.7	283.3	300.0	316.7
Meters	304.8	335.3	365.8	396.2	426.7	457.2	487.7	518.2	548.6	579.1
Pressure (pascals x 10^4)	309.1	340.3	371.6	403.0	434.4	465.9	497.4	529.0	560.7	592.3
Pressure (psi)	448.3	493.6	539.0	584.5	630.0	675.7	721.4	767.3	813.2	859.1

TABLE B-6

(Cont'd)

Feet	Fathoms	Meters	Pressure (pascals x 10^{-4})	Pressure (psi)
2,000	333.3	610	614	890
3,000	500.0	914	921	1,336
4,000	666.7	1,219	1,229	1,783
5,000	833.3	1,524	1,538	2,231
6,000	1,000.0	1,829	1,848	2,680
7,000	1,166.7	2,134	2,157	3,129
8,000	1,333.3	2,438	2,468	3,580
9,000	1,500.0	2,743	2,779	4,031
10,000	1,666.7	3,048	3,091	4,483
11,000	1,833.3	3,353	3,403	4,936
12,000	2,000.0	3,658	3,716	5,390
13,000	2,166.7	3,962	4,030	5,845
14,000	2,333.3	4,267	4,344	6,300
15,000	2,400.0	4,572	4,659	6,757
16,000	2,666.7	4,877	4,974	7,214
17,000	2,833.3	5,182	5,290	7,673
18,000	3,000.0	5,486	5,607	8,132
19,000	3,166.7	5,791	5,923	8,591
20,000	3,333.3	6,096	6,241	9,052
21,000	3,500.0	6,401	6,556	9,508
22,000	3,666.7	6,706	6,874	9,970
23,000	3,833.3	7,010	7,193	10,432
24,000	4,000.0	7,315	7,513	10,896
25,000	4,166.7	7,620	7,833	11,361
26,000	4,333.3	7,925	8,154	11,827
27,000	4,500.0	8,230	8,476	12,294
28,000	4,666.7	8,534	8,798	12,760
29,000	4833.3	8,839	9,120	13,228
30,000	5,000.0	9,144	9,444	13,697
31,000	5,166.7	9,449	9,768	14,167
32,000	5,333.3	9,754	10,093	14,638
33,000	5,500.0	10,058	10,417	15,109
34,000	5,666.7	10,363	10,743	15,581
35,000	5,833.3	10,668	11,070	16,055

NOTES:

(1) Salinity 35 o/oo, Temperature OC.

(2) Calculated with Formula: $P = D_m\ 1.4559 + (D_m \times 0.46 \times 10^{-5})$

Where: D_m = Depth in Meters.

TABLE B-7

Relation Between Various Pressure Units

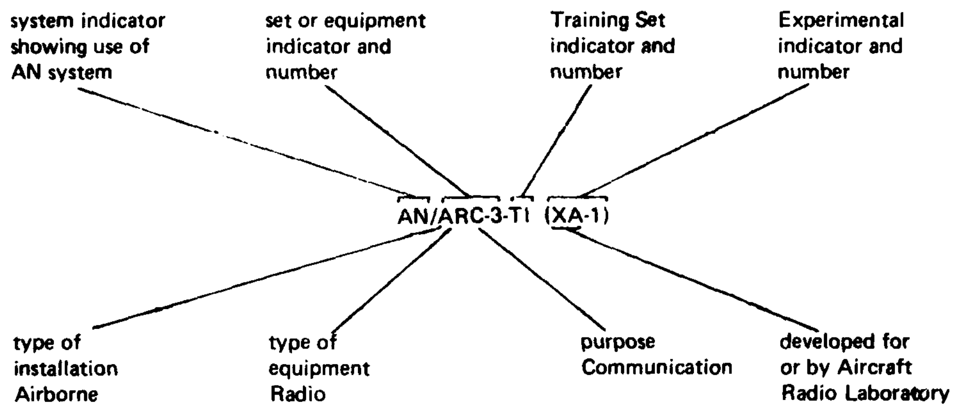
There Are → In ↓	Pascals	Psi	ATM (stnd)	In. Hg.*	mm. Hg.*
pascals	One	6.8948×10^3	1.0132×10^5	3.3820×10^3	8.5903×10^3
psi	6.8948×10^3	One	1.4697×10^1	4.9113×10^{-1}	1.9337×10^{-2}
atm (stnd)	1.0132×10^5	6.8042×10^{-2}	One	3.3418×10^{-2}	1.3157×10^{-3}
In. Hg.*	3.3820×10^3	2.0361	2.9924×10^1	One	3.9371×10^{-2}
mm. Hg.*	8.5903×10^3	5.1717×10^1	7.6008×10^2	2.5400×10^1	One

* 45^{o}F.

TABLE B-8

Summary of Joint Army-Navy nomenclature system

The Joint Army-Navy or AN nomenclature system has been introduced to eliminate confusing and conflicting designations formerly used by the armed services, and to provide a nomenclature that in itself gives a brief description of the article designated. In the AN system, nomenclature consists of a name followed by a type number. The name will be terminology of standard engineering usage, e.g., Radio Receiver, Switchboard, etc. The type number will consist of indicator letters shown below, and an assigned number. Additional symbols are added as required. An example is



Nomenclature policy

AN nomenclature will be assigned to:

a. Complete sets of equipment and major components of military design.

b. Groups of articles of either commercial or military design that are grouped for a military purpose.

c. Major articles of military design that are not part of or used with a set.

d. Commercial articles when nomenclature will facilitate military identification and/or procedures.

TABLE B-8
(Cont'd)

AN nomenclature will not be assigned to:

a. Articles cataloged commercially except in accordance with paragraph (d) above.

b. Minor components of military design for which other adequate means of identification are available.

c. Small parts such as capacitors and resistors.

d. Articles having other adequate identification in American War Standard or Joint Army-Navy Specifications.

Nomenclature assignments will remain unchanged regardless of later stages in installation and/or application.

Set or equipment indicator letters

type of installation	type of equipment	purpose
A Airborne	A Invisible light, heat radiation	A Auxiliary assemblies (not complete operating sets)
B Underwater mobile, submarine	B Pigeon	B Bombing
C Air transportable (inactivated, do not use)	C Carrier (wire)	C Communications
D Pilotless carrier	D Radiac	D Direction finder
F Ground, fixed	F Photographic	
G Ground, general ground use includes two or more ground installations)	G Telegraph or teletype (wire)	G Gun directing
		H Recording (photographic, meteorological, and sound)
	I Interphone and public address	
		J Countermeasures
K Amphibious	K Telemetering	
	L Countermeasures	L Searchlight control
M Ground, mobile in a vehicle which has no function other than transporting the equipment	M Meteorological	M Maintenance and test assemblies

TABLE B-8
(Cont'd)

Set or equipment indicator letters (Continued)

type of installation	type of equipment	purpose
	N Sound in air	N Navigational arts
P Ground, pack, or portable	P Radar	P Reproducing (photographic and sound)
	Q Underwater sound	Q Special, or combination of types
	R Radio	R Receiving
S Shipboard	S Special types, magnetic, etc, or combinations of types	S Search
T Groups, transportable	T Telephone (wire)	T Transmitting
U General utility, includes two or more general classes		
V Ground, vehicular, installed in vehicle designed for other functions, i.e., tanks	V Visual and visible light	
W Underwater, fixed		W Remote control
	X Facismmile or television	X Identification and recognition

APPENDIX C

LISTING OF SUPPLIERS AND PERSONNEL INVOLVED IN PRESSURE-PROOF CABLE, CABLE HARNESS, CONNECTOR, AND HULL PENETRATOR DESIGN AND USE

Business/Organization	Personnel	Product/Interest
Ametek Straza Division 790 Greenfield Drive P.O. Box 666 El Cajon, CA 92022 714-442-3451	H. Lewis- Engineer Jay Harford Manager, Wash. Office	Hydrophones Transducers Cable Harnesses
Advanced Cable & Assembly 10841 Laurel Avenue Santa Fe Springs, CA 90670 213-944-9937	A. Bertoldo - President	Connectors Penetrators Cable Harnesses
Arthur L. Nelson & Company Consulting Ocean Engineers P.O. Box 9745 San Diego, CA 92109 714-270-4750	A. Nelson- PE	Connectors Cable Splices
April Engineering Corp 901 River Road Mystic, Ct 06355 203-536-1454	E. April	Electer-Mechanical Cable Optical Electer-Mech Cable Cable Systems
Artisan Electronics 5 Eastmans Road Parsippany, NJ 07054 201-887-7100	M. Gruenspecht	Harnesses
Ameeco (Hydrospace) Ltd Bilton Road Erith, Kent England ERITH 46821-23	W. Wyatt	Harnesses Connectors Penetrators Hydrophones Transducers
Applied Physics Laboratory University of Washington 1013 N.E. 40th St. Seattle, WA 98105 206-543-1300	Colin Sandwith Elbert Pence Edward Early William Lewis	Hydrophones Transducers Connector Seals Harnesses Arrays Failure Analysis
Analysis & Technology P.O. Box 769 New London, Ct. 06320 203-443-1140	G. Sefcik	Hydrophones Transducers

Business/Organization	Personnel	Product/Interest
Bendix Electrical Components Division Sidney, NY 13838 607-563-5649	D. Werth- Engineer	Cable Harnesses Connectors Penetrators
Brantner Associates 3501 Hancock Street San Diego, CA 92110 714-297-2828	B. Seilhan- President	Cable Harnesses Connectors Penetrators
Burton Electrical Engineering 111 Maryland Street El Segundo, CA 90245 213-772-1406	H. Doty- Sales Manager Ed Beacham - Ch. Engineer	Cable Harnesses Connectors Penetrators
BIW Cable Systems, Inc. 65 Bay Street Boston, MA 02125 617-265-2102 (Formerly Boston Insulated Wire and Cable Co.)	R. Kruger- Prod. Manager A. Ruprecht- Eng. Manager	Cables Harnesses Connectors
Bendix-Electrodynamics Corporation 15825 Roxford Street Sylmar, CA 91342 213-367-0111	G. Harsha R. Bridges J. Martin R. Winnicki	Cables Connectors Hydrophones Transducers
Bedford Institute of Oceanography P.O. Box 1006, Bzy, 4A2 Dartmouth NS. Canada 902-426-8142	J. Dessureault	Transducers Hydrophones
Bell Laboratories Whippany, N.J. 07974 201-386-2563	J. Richey	

Business/Organization	Personnel	Product/Interest
Celmark Engineering, Inc. 9822 Independence Ave Chatsworth, CA 91311 213-998-0244	J. Schaefer-President A. Glowacz-Gen. Manager	Connectors Harnesses Penetrators
Cameron Iron Works, Inc. P.O. Box 1212 Houston, TX 77001 713-683-2021	W. Miller J. Corman R. Rodman	Harnesses Connectors Penetrators
Cyprus Wire & Cable Company 421 Ridge Street P.O. Box 71 Rome, NY 13340 315-337-3000		Cable
Crouse-Hinds Electro 15146 Downey Avenue Paramount, CA 90723 213-630-4252	B. Marshall-Gen. Manager J. Rudesill-QC Manager	Connectors Penetrators Harnesses
Custom Cable Company 5310 Glenmont Houston, TX 77081 713-666-6301	C. Manning-Sales Manager	Cable Harnesses
Chesapeake Instrument Company 6711 Baymeadow Drive Glen Burnie, MD 21061 301-760-3100	W. Paul, Sr. Engineer	Transducers Hydrophones
Consolidated Products Corporation Box 67 Idyllwild, CA 92349 714-659-2183	G. Brown-President N. Roe-Ch. Engineer	Cables Connectors Harnesses
Civil Engineering Laboratory Naval Construction Battalion Center Port Hueneme, CA 93043 805-982-4623	J. Wilson P.E.	Cables Connectors Splices

Business/Organization	Personnel	Product/Interest
(Cont'd)		
Cortland Line Company 67 E. Court Cortland, NY 13045 607-756-2851	E. Scala J. Dower	Cables
Cambridge Marine Industries, Inc., 10 Industry Drive Lancaster, PA 17603 (717) 397-2777	P. Szulborski Mkt. Director.	Connectors Penetrators
Chesapeake Naval Facilities Engineering Command Washington Navy Yard Washington, D. C. 20374 203-433-3881	J. Martin L. Mendlow T. O'Boyle H. Dorin	
D.G. O'Brien, Inc. 1 Chase Park P.O. Box 159 Seabrook, NH 03874 603-474-5571	P. Doringer- Sales Manager H. Hilberg- Ch. Engineer W. Sowers- Sr. Engineer	Harnesses Connectors Penetrators
E.I. duPont de Nemours & Company Kevlar Special Products Chestnut Run-Bldg 701 Wilmington, DE 19898 302-999-3030	J. Alexander- Marketing M. Horn- Sr. Res. Engineer	Cables
David Taylor Naval Ship R&D Center Annapolis, Md. 21114 301-267-2466	J. Tobin R. Bloomquist E. Diamond W. Jones R. Forbes W. Kenney	Cables Testing

Business/Organization	Personnel	Product/Interest
Envirocon Division Rochester Corporation 5725 Hartsdale Drive Houston, TX 713-782-5350	D. Guy- Manager	Harnesses Connectors Penetrators
Edo Corporation 13-10 111th Street College Point, NY 11356 212-445-6000	R. Becker- Engineer L. Carter- Engineer	Hydrophones Transducers Harnesses
Engineering Services Associates 1500 Mass. Ave. N.W. Washington, DC 20005 202-659-8800	R. Champ- President	Cables Connectors Harnesses Hydrophones Transducers
Exxon Production Research Corporation P.O. Box 2189 Houston, TX 77001 713-965-4088	D. Reed	
Electric Boat Division General Dynamics Corp. Groton, CT, 06340 203-446-2825	R. Haworth Q. Long D. Odryna E. Hobaica E. Zuraw E. Budzik	Cables Harnesses Connectors Penetrators Materials FMEA
Excon, Inc. 215 Jupiter Street Jupiter, FL 33458 305-746-9619		Harnesses Connectors Cables Penetrators Transducers
FKC Engineering Company 185 York Avenue Pawtucket, RI 02861 401-724-1760	F. Coppell- President	Harnesses Connectors Penetrators

Business/Organization	Personnel	Product/Interest
G.W. Dahl Company 86 Tupelo Street Bristol, RI 02809 401-253-9500	R. Kraimer- Sr. Engineer Barry Lowe	Harnesses Connectors
Gulf & Western Ind., Inc. General Products Division 107 Salem Street Union Springs, NY 13160 315-889-7361	C. Mears- Sales Engineer	Harnesses Connectors Penetrators
Glenair, Inc. 1211 Air Way Glendale, CA 91201 213-247-6000	G. Burge- Ch. Engineer J. Iacobucci- Manager R&D	Cables Harnesses Connectors
G & H Technology, Inc. 1649 17th Street Santa Monica, CA 90404 213-871-0760	W. Powell- Sales Manager J.R. Reedy	Connectors
GULTON Connector Division 6400 Roland Avenue Buena Park, CA 90621 714-523-3480	H. Potter- Engineer	Harnesses Connectors Penetrators
General Electric Company Transducer Prod. Operation Farrell Road Plant Syracuse, NY 13207 315-456-4516	L. Izzo R. Teza Xducer Engr. Mgr D. Connelly	Hydrophones Transducers Harnesses Connectors Penetrators
General Dynamics-Convair Division P.O. Box 80847 San Diego, CA 92138 714-277-8900 x1502	J. Burkhardt- Sr. Engineer	Cables Connectors Penetrators
Global Marine Development 4100 McCarthur Blvd. Newport Beach, CA 92660 714-752-5050	A. Klann- Elec. Engineer	

Business/Organization	Personnel	Product/Interest
(Cont'd)		
General Oceanics, Inc. 5535 N.W. 7th Avenue Miami, FL 33127 305-754-6658		Connectors Oceanographic Equipment
Gearhart-Owen Ind., Inc. P.O. Box 1936 Fort Worth, TX 76101 817-293-1300		Harnesses Connectors
GOULD, Inc. Advanced Development Division 18901 Euclid Avenue Cleveland, OH 44117 216-486-8300	M. Baum	Harnesses Connectors Hydrophones Transducers
General Instrument Corp Govt. Systems Div 33 Southwest Industrial Park Westwood, MA 02090	A. Poturnicki	Hydrophones Transducers
Hermetic Seal Corporation 4232 Temple City Blvd. Rosemead, CA 91770 213-283-0411	D. Allen- Sales Manager J. Goldfarb- President M. Pelta - Vice President C. Burtz- Market Manager	Connectors Penetrators
Hazeltine Corporation 115 Bay State Drive Braintree, MA 02184 617-848-3400	J. Wade- Manager	Hydrophones Transducers Harnesses
Honeywell, Inc. Marine Systems Center 5303 Shilshole Ave., N.W. Seattle, WA 98107 206-789-2000	L. Armbruster- Sr. Dev. Engineer L. Jones	

Business/Organization	Personnel	Product/Interest
Hydro Products 11777 Sorrento Valley Road San Diego, CA 92121 714-453-2345	R.S. Mathews- Oc. Eng. Manager J. Jaeger Eng. Director J. Reiss- Engineer P. Hurst- Sr. Engineer	
Hughes Aircraft Corporation Underseas Systems Lab. P.O. Box 3310, MS609/D232 Fullerton, CA 92634 714-732-4929	R. Halushla	
Helle Engineering, Inc. 7189 Convoy Court San Diego, CA 92111 714-278-3521	L. Cuprys- Mech. Engineer	
The Heckerman Corporation 814 West Hyde Park Blvd. Inglewood, CA 90302 213-678-2264	P. Morgan- Vice President F. Heckerman- President	
Hydril Advanced Ocean Systems 5600 Bintliff Houston, TX 77036 713-977-0366	A. Cope- Prod. Manager B. Mundy- Sales Engineer	
Hexcel Corporation 20701 Nordhoff Street Chatsworth, CA 91311		Splices

Business/Organization	Personnel	Product/Interest
ITT Cannon Electric Division Phoenix Operation 2801 Air Lane Phoenix, AZ 85034 602-275-4792	G. Panek- Sales Manager F. Ingham- Engineering Supervisor A. Sedig- Sr. Engineer	Connectors Harnesses Penetrators
ITT 7635 Plantation Road Roanoke, Va 24109 703-563-0371	R. Thompson	Fiber Optic Cables
International Transducer Corp. 640 McCloskey Place Goleta, CA. 93017 805-967-0491	G. Liddiard	Hydrophones Transducers
Joy Manufacturing Company 338 South Broadway New Philadelphia, OH 44663 216-343-3351	D. Robinson- Gen. Manager R. Swan - Engineer D. Oehlesking- Eng. Manager	Harnesses Connectors Penetrators

Business/Organization	Personnel	Product/Interest
Kintec, Inc. 9547 Cozy Croft Avenue Chatsworth, CA 91311 213-998-8822	N. Karlskind- Vice President	Harnesses Connectors
Kemlon Products and Development Company P.O. Box 14666 Houston, TX 77021 713-747-5020	S. King	Harnesses Connectors
L.L. Rowe Company 66 Holton Street Woburn, MA 01801 617-729-7860	R. Ashenden- Vice President H. Nolan - President	Harnesses Connectors Penetrators
Lockheed Missiles & Space Company Lockheed Ocean Laboratory 3929 Calle Fortunata San Diego, CA. 92123 714-569-8540	E. Niekrasz- Supvor. Mech. Systems Group W. Saunders Sr. Engineer	Harnesses Connectors Penetrators Transducers Hydrophones
Lebus International, Inc Box 2352 Longview, TX 75606 214-758-5521	R. Smith	Cable Reels

Business/Organization	Personnel	Product/Interest
Mark Products, Inc. 10507 Kinghurst Drive Houston, TX 77072 713-498-0600		Connectors
Mare Island Naval Shipyard Code 280.33 Vallejo, CA 94592 707-646-2227	P. Loomis-Engineer T. Yee F. Peglow M. Martin R. Bisnett	Cables Connectors Harnesses Penetrators
Magnanox Government and Industrial Electronics Co. 1313 Production Road Fort Wayne, IN 46808	D. Kulpa	Hydrophones Transducers Cable Connectors Harnesses
Naval Ocean Systems Center San Diego, CA 92152 814-225-2486	D. Carson G. Hunsaker J. Benya S. Cowen J. Wong	Cables Connectors Harnesses Transducers Hydrophones
Naval Underwater Systems Center New London, CT 06320 203-442-0771	T. Susi J. Redding J. Gagne J. Orr E. Racine R. Gerlipp T. Mapes R. Maple G. De La Cruz E. Pearson H. Malootian R. DeAngelis C. LeBlanc	Cables Connectors Harnesses Penetrators Materials

Business/Organization	Personnel	Product/Interest
Naval Ocean Systems Center Hawaii Laboratory P.O. Box 997 Kailua, HA 96734 808-254-4433	G. Wilkins M. Hascall D. Rosencrantz H. Hascall T. Hoffman	Cables
Naval Research Laboratory Underwater Sound Reference Division P.O. Box 8337 Orlando, FL 32856 305-859-5120	Dr. R. Timme- Branch Head G.D. Hugus- Sr. Engineer A. Young C. Thompson	Cables Connectors Harnesses Penetrators Transducers Hydrophones Materials
Naval Research Laboratory Material Science & Technical Division Washington, D.C. 20375 201-767-2970	M. Peterson- P.E.	Materials
Naval Coastal Systems Center Code 753 Panama City, FL 3840[illegible]	R. Lovejoy	Cables Connectors Harnesses
Naval Weapons Support Center Crane, IN 47522 812-854-1832	D. Moore P. Henderson D. Steele C. Olds	Cables Connectors Harnesses Hydrophones Transducers
Naval Ocean R&D Activity Ocean Technology Division Code 350 NSTL Station, MI 39529 601-688-4702	R. Swenson Head	Cables Connectors

Business/Organization	Personnel	Product/Interest
(Cont'd)		
Naval Sea Systems Command Electrical Division National Center No. 4 NAVSEA 5433 Washington, DC 20362 202-692-6794	J.E. Regan	Harnesses Cables Connectors Penetrators
Naval Sea Systems Command Electrical Division National Center No. 4 Washington, DC 20362 202-692-2748	S. Wong	Cables
Naval Sea System Command NAVSEA 05R2 Washington, DC 20362 202-647-2433	J. Freund	R&D Cables Connectors Harnesses Penetrators
Naval Sea Systems Command NAVSEA 63XT Washington, DC 20362 202-692-7840	R. Heaney C. Clark	Sonar Systems
Nova Scotia Research Foundation Corp. 100 Fenwick St Dartsmouth, N.S., Canada 902-424-8670	F. Smith	
Newport News Shipbuilding and Drydock Co. 4101 Washington Ave Newport News, Va 23607 804-380-4193	S. Modlin B. Green R. Swain D. Huebner	Cable Harnesses Connectors Hull Penetrators Hydrophones Transducers

Business/Organization	Personnel	Product/Interest
(Cont'd)		
Norfolk Naval Shipyard Portsmouth, Va 23709 804-393-5144	H. Renshaw	Hull Penetrators Cables Harnesses Connectors
Naval Surface Weapons Center White Oak Silver Springs, Md. 20910 301-394-2752	R. Lyon G. Reic	Cable Connectors Hull Penetrators Harnesses
National Electric Cable 16566 S.W. 72nd Avenue Portland, OR 97223 503-620-9400	R. Sass- President	Cables
N.L. Petroleum Services P.O. Box 1473 Houston, TX 77001 713-466-4828	R. Hargett- Sr. Engineer	
The Okonite Company P.O. Box 340 Canal & Jefferson Streets Passaic, NJ 07055 201-777-0400	A. Dechiara	Cables

Business/Organization	Personnel	Product/Interest
Precision Cable of Tennessee, Inc. 504 Steam Plant Road Gallitan, TN 37066 615-452-7258	F. Porter-President E. Lacey-Engineer	Harnesses
Preformed Line Products Company Marine Systems Division P.O. Box 91129 Cleveland, OH 44101 216-461-5200	W. Stange-Eng. Mana	Cable Testing
Pacific Missile Test Center Code 3143 Point Magu, CA 93042 805-982-8904	R. Polley, Jr.	
Philadelphia Resins Corporation P.O. Box 454 20 Commerce Drive Montgomeryville, PA 18936 215-855-8450	G. Bowen	Cable
Robert A. Patterson, Inc. P.O. Box 45 Hampstead, NH 03841 603-329-5369	R. Patterson	Cable Connectors Penetrators Harnesses Cable Terminations
Perry Oceanographic P.O. Box 10297 Riviera Beach, Fl 33458 305-842-5261	H. Miller	Cables Harnesses Connectors Hull penetrators Splicers

Business/Organization	Personnel	Product/Interest
(Cont'd)		
Portsmouth Naval Shipyard Portsmouth NH 03801 207-439-1000	A. Bratt B. Stultz B. Parsons J. Marshall J. Lovell	Cables Connectors Hull penetrators Hydrophones Transducers Harnesses
Pugent Sound Naval Shipyard Bremerton, WA 98314 206-478-3855	G. Lewis G. Dietrich	Cable Harness Connectors Hull penetrators
Pearl Harbor Naval Shipyard Transducer Repair Facility Pearl Harbor, HI 96860	R. Shigeta R. Okimoto	Hydrophones Transducers Harnesses Cables Connectors
Porterfield, Inc. 2591 Wimbledon St. Napa, CA. 94558	C. Porterfield Consultant	Hydrophones Transducers Harnesses Connectors Cables FMEA

Business/Organization	Personnel	Product/Interest
Rochester Corporation Electrical Products Division P.O. Box 312 Culpeper, VA 22701 703-825-2111	A. Berian A. Crane	Cables
Rebikoff Underwater Products Institute of Marine Technology 3060 S.W. 4th Avenue Fort Lauderdale, FL 33315 305-522-5572	D. Rebikoff President	Cameras Connectors Harnesses
Raytheon Company Submarine Signal Division P.O. Box 360 Portsmouth, RI 02871 401-847-8000	K. Turner D. Ricketts N. Serotta	Hydrophones Transducers
RCA Camden Building 10-1-2 Camden, NJ 08108 609-338-2992	S. Ranner	
Rockwell International 3370 Mira Loma Anaheim, CA 92803	C. Yarbrough	
Rowe Industries 6225 Benore Road Toledo, OH 43612 419-729-9761	R. Smith - Sales Manager	Connectors Harnesses
Raychem 300 Constitution Drive Menlo Park, CA 94025 415-361-3082	K. Benner E. Fenton	Splices Shrink Tubing

Business/Organization	Personnel	Product/Interest
Sanders Associates, Inc. Ocean Systems Division 95 Canal Street Nashua, NH 03061 603-885-3719	J. Feeley	Hydrophones Transducers
Spears Associates, Inc. 249 Vanderbilt Avenue Norwood, MA 02062 617-769-6900	J. Ryan Ashton Shoop	
Southwest Research Institute 6220 Culebra Road San Antonio, TX 78284 512-684-5111 X278	E. Briggs-Engineer	Connectors Hydrostatic Testing
Standard Telephones & Cables, Ltd. ITT Hydrospace Division Christchurch Way Greenwich, London SE10 OAG 01-858-3291 Wash. Office 202-296-6000	A. Samson-General Manager J. Jermyn-Cable Engineer J. Condie W. Whitaker J. Everett-Tech. Manager L.R. Spicer	Cables Connectors Harnesses Penetrators
South Bay Cable Division Consolidated Products Corporation P.O. Box 853 Idyllwild, CA 92349 714-659-2183	N. Roe-Ch. Engineer G. Brown-President	Cables Harnesses Connectors
Simplex Wire & Cable Company P.O. Box 479 Portsmouth, NH 03801 603-436-6100	H. Blumsack-Engineer B. Clark-Dev. Engineer P. Buckley J. Runfola J. Schultz	Cables

Business/Organization	Personnel	Prod ct/Interest
(Cont'd)		
Souriau & Cie 9-13 Rue Gl-Gallieni 92103 Boulogne-Bill/Cedex France, BP-410 33-1-609-92-00	C. Hatem	Connectors Cables Harnesses Penetrators
Sparks & Company 4853 Cordell Avenue Bethesda, MD 20014 301-656-4343	M. Sparks	Connectors Cables Harnesses Penetrators
Sperry Systems Mgt. Great Neck, N.Y. 11020 516-574-0111	T. Sargent	Transducers Hydrophones

Business/Organization	Personnel	Product/Interest
Times Wire & Cable Company Insilco Corporation 358 Hall Avenue Wallingford, CT 06492 203-265-2361	D. Peterson- Manager Engr. R. Hugo	Cables Harnesses Connectors
Texas Research Institute 5902 W. Bee Coves Road Austin, TX 78746 512-327-2882	Dr. S. Thornton- Technical Direc. D. Barrett- Sr. Scientist D. Glowe- Sr. Engineer	Cables Connectors Harnesses Hydrophones Transducers
Tension Member Technology 15161 Golden West Circle Westminster, CA 92683 714-898-5641	P. Gibson- President J. Walther- Test Director	Cable Testing
Tracor Sciences and Systems Tracor, Inc. 1601 Research Blvd Rockville, Md. 20850 301-279-4200	P. Flannery Senior Scientist J. McClung	Sonar Systems
Teledyne Mecca P.O. Box 36393 Houston, Texas 77036 713-772-2811	D. Knapp	Cables Connectors Harnesses

Business/Organization	Personnel	Product/Interest
University of Rhode Island Graduate School of Oceanography Narragansett, RI. 02882 401-294-2863	A. ⁻iscoll	Hydrophones Transducers
Vector Cable Company 555 Industrial Road Sugarland, TX 77478 713-491-9196	R. Cates- Sales Manager Dr. R. McNerney- Manager Material D. O'Hara- Sr. Sales Engineer E. Felkel- Cable Consultant	Cables Harnesses Connectors Penetrators
Viking Industries, Inc. Special Products Division 9324 Topanga Canyon Blvd. Chatsworth, CA 91311 213-882-6275	S. Langham- Direc. Engineer L. Neeb- Tech. Consultant A. Pusateri- Super. Engineer H. Weiner- Prod. Eng. Manager	Harnesses Connectors Penetrators

Business/Organization	Personnel	Product/Interest
Westinghouse Electric Corporation Oceanic Division Box 1488 Annapolis, MD 21404 301-765-5234	C. Hikes A. Haury R. Leitholf J. Pritzlaff E. Opdahl E. Stearns	Harnesses
Wall Rope Works Beverly, NJ 08010 609-877-1800	H. Alexander Hood- Product Manager	Cables
Woods Hole Oceanographic Institute Woods Hole, MA 02543 617-548-1400	H. Berteauz- Res. Spec. S. Marquet- Sr. Engineer D. Moller	Cables Connectors Harnesses Penetrators
Western Electric Co. Guilford Ctr P.O. Box 20046 Greensboro, N.C. 27420 919-697-4487	G. Boland H. Boyd	Transducers Hydrophones
Zippertubing Company 13000 Broadway Los Angeles, CA 90061 213-321-3901	J. Maurer- Product Manager	Splices Tubings
New Jersey Office 201-256-4980	J Walsh	

APPENDIX D

DISTRIBUTION LIST FOR THIS REPORT

Commander
Naval Air Development Center
Warminister, PA 18974
ATTN: Code 3043, R.A. DeChico (1)

Commanding Officer
Naval Coastal Systems Center
Panama City, FL 32407
ATTN: Code 750A, R.L. Cook (1)
Code 753, R. Lovejoy (1)
Code 790, D.F. Folds (1)
Technical Library (1)

Officer-in-Charge
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, CA 93043
ATTN: Code L43, J.V. Wilson (1)

Chesapeake Naval Facilities Engineering
Washington Navy Yard
Washington, DC 20374
ATTN: J. Martin (1)

Commander
Naval Material Systems Command
Washington, DC 20360
ATTN: Dr. J.A. Sinsky (1)

Commander
Naval Ocean Systems Center
271 Catalina Blvd.
San Diego, CA 92152
ATTN: Code 712, D.L. Carson (1)
Code 712, J. Fransdal (1)
Code 713, Dr. J. Lockwood (1)
Code 6233, John Benya (1)
Technical Library (1)

Commanding Officer
Naval Ocean Research & Development Activity
NSTL Station, MS 39529
ATTN: Library (1)

Commanding Officer
Naval Research Laboratory
Washington, DC 20375
ATTN: Code 2628 (20)
Code 2628 (12 cys for DTIC)
Code 5000 (1)

Commander
Naval Sea Systems Command
Washington, DC 20362
ATTN: SEA05H, C.C. Taylor (1)
SEA05N(SMMSO), J. Pratchios (1)
SEA06H5-21, Ms. D.B. Bagley (1)
SEA5443, S. Wong (1)
SEA63ECD, H. Evans (1)
SEA63FP5, S.S. Shimomura (1)
SEA63R-12, C.C. Walker (1)
SEA63X, CAPT P.W. Sparks (1)
SEA63X5 (1)
SEA63X5B, R.E. Heaney (1)
SEA63X5-1, C.A. Clark (3)
SEA63X5-2, P. Greenhaus (1)
SEA63X5-3, V. Graves (1)
SEA63X5-4, T.G. Martin (1)
SEA63X5-5, B.E. McTaggart (1)
Code 5433, J.E. Regan (1)
PMS395-A3, R. Wallace (1)

Commanding Officer
Naval Ship Engineering Center
Norfolk Division
U.S. Naval Station
Norfolk, VA 23511 (1)

Commander
Naval Ship Engineering Center
Washington, DC 20362
ATTN: Tech. Library (1)

Department of the Navy
Ships Parts Control Center
PO Box 2020
Mechanicsburg, PA 17055
ATTN: Code 3821, R. Carr (1)

DISTRIBUTION LIST (cont'd.)

Commander
Charleston Naval Shipyard
Charleston, SC 29408
ATTN: Code 270, W. Morgan (1)

Commander
Mare Island Naval Shipyard
Vallejo, CA 94592
ATTN: M. Martin (1)
Code 280.2 Stop 060 (1)
Library, Code 202.1 (3)

Commander
Norfolk Naval Shipyard
Portsmouth, VA 23709
ATTN: Code 275, Bldg. 30, J. Harris (1)

Commander
Portsmouth Naval Shipyard
Portsmouth, NH 03801
ATTN: Code 967.73, W.W. Lovell (6)
Code 270, A. Bratt (1)

Commander
Puget Sound Naval Shipyard
Bremerton, WA 98314
ATTN: Code 270.42, G. Lewis (1)

Commander
D.W. Taylor Naval Ship R&D Center
Bethesda, MD 20084
ATTN: Tech. Library (1)
Code 2713, J. Tobin (1)
E. Diamond (1)

Commander
Naval Surface Weapons Center
Dahlgren Laboratory
Dahlgren, VA 22448
ATTN: Code DX-21, Library (1)

Commander
Naval Surface Weapons Center
White Oak Laboratory
Silver Springs, MD 20910
ATTN: Tech. Library (1)

Commanding Officer
Transducer Repair Facility
Mare Island Naval Shipyard
Vallejo, CA 94592
ATTN: Code 270.301, Tow Yee (2)
F. Peglow (1)
Code 280, Paul Loomis (1)

Commanding Officer
Transducer Repair Facility
Pearl Harbor Naval Shipyard
Pearl Harbor, HI 96860
ATTN: Code 270.3, R. Okomoto (2)
Code 270.3, R. Shigeta (2)

Commanding Officer
Naval Undersea Warfare Engineering Station
Keyport, WA 98345
ATTN: Tech. Library (1)
C. Bray (1)
Quality Evaluation Lab (1)

Commanding Officer
Naval Underwater Systems Center
New London Laboratory
New London, CT 06320
ATTN: Code 316, J. Redding (1)
Code 316, Dr. C.H. Sherman (1)
Code 316, T.J. Mapes (1)
Code 316, R. DeAngelis (1)
Code 3232, G. Connolly (1)
Code 3233, J. Gagne (1)
Code 342, T. Suzi (1)
Code 344, J. Orr (1)
Code 4111, B. Silver (1)
Code 4123, E. Pearson (1)
Tech. Library (1)

Commanding Officer
Naval Weapons Support Center
Crane, IN 47522
ATTN: Code 705, D. Miley (1)
Code 7055, D.J. Steele (1)
Code 70553, T. Peter (1)
Code 70554, Paul Henderson (1)
C. Olds (1)
Tech. Library (1)

Superintendent
Underwater Sound Reference Detachment
Naval Research Laboratory
PO Box 8337
Orlando, FL 32856
ATTN: Code 5905.2 (42)

Director of Fleet Maintenance (UW)
Department of Defense (Navy)
Campbell Park 1 (Room 3-11)
Canberra, A.C.T. 2600 Australia (1)

Institute of Marine Technology
PO Box 181, Simonstown 7995
Republic of South Africa
ATTN: Mr. L. Krige (1)

DISTRIBUTION LIST (cont'd.)

Mulloka Project Director - Navy
Department of Defence (Navy)
Campbell Park 2 (Room 1-24)
Canberra, A.C.T. 2600 Australia
ATTN: CDR P. Hart (1)

Materials Research Laboratory
PO Box 50
Ascot Vale, Victoria, Australia
ATTN: Dr. D. Oldfield (1)

Plessey (Australia) PTY Ltd.
Faraday Park Road
Meadowbank, N.S.W. 2114 Australia
ATTN: G. Tulloch (1)

Defence Research Establishment Atlantic
Grove Street
Dartmouth, Nova Scotia, Canada
ATTN: Mr. G.W. McMahon (1)

Nova Scotia Research Foundation Corp.
100 Fenwick St.
Dartmouth, Nova Scotia, Canada BOJ1LO
ATTN: Floyd M. Smith (1)

Defence Equipment Center
British Defence Staff
British Embassy
Washington, DC 20008
ATTN: Derek Palmer, Mat'ls Officer (1)

Plessey Company Ltd.
Plessey Marine Research Unit
Templecombe, Somerset, England
ATTN: W. Craster (1)

Actran Electroacoustics, Inc.
1012 Maltby Ave.
Orlando, FL 32803
ATTN: Mr. C. C. Sims (1)

Ametek Straza
790 Greenfield
El Cajon, CA 92022
ATTN: Hd., Transducer Engr. (1)

April Engineering Corp.
901 River Rd.
Mystic, CT 06355
ATTN: Ed. P. April, Pres. (1)

Battelle Memorial Institute
505 King Ave.
Columbus, OH 43201
ATTN: R.J. Dick (1)

Bendix Corp.
Electrical Components Division
Sidney, NY 13838 (1)

Bendix Electrodynamics
15825 Roxford St.
Sylmar, CA 91342
ATTN: Mr. J. Martin (1)

Bolt Beranek & Newman Inc.
50 Moulton St.
Cambridge, MA 02138
ATTN: N. Higbie (1)

Boston Insulated Wire & Cable Co.
65 Bay St.
Boston, MA 02125
ATTN: J. Jeanmonod (1)

Brantner & Associates, Inc.
3501 Hancock St.
San Diego, CA 92110
ATTN: Patrick Simar (1)

Brand-Rex Co.
6600 York Rd.
Baltimore, MD 21212
ATTN: L. Supsic (1)

Breech-Lock
G&H Technology Inc.
PO Box 687
Lake Mary, FL 32746
ATTN: J.R. Reedy (1)

Cameron Iron Works, Inc.
PO Box 1212
Houston, TX 77001
ATTN: R.M. Rodman (1)

Chesapeake Instrument Co.
6711 Baymeadow Dr.
Glen Burnie, MD 21061
ATTN: W. Paul (1)

DISTRIBUTION LIST (cont'd.)

Consolidated Products Corp.
South Bay Cable Division
Box 67
Idyllwild, CA 92349
ATTN: N. Roe (1)

Cortland Line Co.
Advanced Products Div.
67 E. Court St.
Cortland, NY 13045
ATTN: Dr. E. Scala, Director (1)

Dyna-Empire, Inc.
1075 Stewart Ave.
Garden City, LI, NY 11530
ATTN: A. Backran (1)
E. Freidel (1)

Edo Corp.
14-04 111th St.
College Point, NY 11356
ATTN: W. Straurenberg (1)
S. Schildkraut (1)

Edo Western
2645 South 300 West
Salt Lake City, UT 84115
ATTN: D. Bonnema (1)
G.L. Snow (1)

Cee & Jenson
Engineers-Architects,Planners, Inc.
2019 Okeechobee Blvd.
West Palm Beach, FL 33409
ATTN: Gerald M. Ward, P.E. (1)

General Electric
PO Box 4840
Syracuse, NY 13221
ATTN: J. Dietz (1)
L. Izzo (1)

General Dynamics Corp.
Electric Boat Div.
Groton, CT 06340
ATTN: R.F. Haworth (25)

General Instrument Corp.
Government Systems Div.
33 Southwest Industrial Park
Westwood, MA 02090
ATTN: D. White (1)

Gould, Inc.
Ocean Systems Div.
18901 Euclid Ave.
Cleveland, OH 44117
ATTN: M.R. Collins (1)

Gulton Connector Div.
6400 Roland Ave.
Buena Park, CA 90621
ATTN: H. Potter (1)

Hazeltine Corp.
115 Baystate Dr.
Braintree, MA 02184
ATTN: G.W. Renner (1)

Honeywell, Inc.
Marine Systems Center
5303 Shilshole Ave., NW
Seattle, WA 98107
ATTN: C. Sheets (1)
O.L. Ackervold (1)

Honeywell, Inc.
Honeywell Ceramics Center
5121 Winnetka Ave. N
New Hope, MN 55428
ATTN: D.W. Bacso (1)

Hydro Products
11777 Sorrento Valley Rd.
San Diego, CA 92121
ATTN: Mrs. P. Hurst (1)

International Transducer Corp.
640 McCloskey Pl.
Goleta, CA 93017
ATTN: G.E. Liddiard (1)

ITT Canon Electric
2801 Air Lane
Phoenix, AZ 85036
ATTN: Kerry Willis (1)

Lockheed Missiles & Space Co., Inc.
Lockheed Ocean Laboratory
3929 Calle Fortunada
San Diego, CA 92123
ATTN: Mr. E.J. Nickrasz (1)

Massachusetts Institute of Technology
Cambridge, MA 02139
ATTN: Prof. J. Paradis, 14N-306,
Humanities Dept. (1)

DISTRIBUTION LIST (cont'd.)

Newport News Shipbuilding &
Drydock Company
Dept. E23
4101 Washington Ave.
Newport News, VA 23607
ATTN: R. Swain (1)
S. Modlin (1)

D. G. O'Brien, Inc.
PO Box 159
Seabrook, NH 03874
ATTN: Mr. D. G. O'Brien (1)

Okonite Co.
PO Box 340
Ramsey, NJ 07446
ATTN: A. Dechiara (1)

Perry Ocean Engineering
275 W. 10th St.
PO Box 10297
Riviera Beach, FL 33404
ATTN: Harvey A. Miller, P.E. (1)

Raytheon Co.
Submarine Signal Division
PO Box 360
Portsmouth, RI 02871
ATTN: N. Serotta, K_{33} Transd. Program Mgr. (1)
D. Ricketts, Consultant, Design Engr. Lab. (1)
M. Ralyea, Mgr., Transd. Dept. (1)

The Rochester Corp.
Electrical Products Div.
PO Box 312
Culpepper, VA 22701
ATTN: A.H. Crane (1)
A. Berian (1)

Sanders Associates
Ocean Systems Div.
95 Canal St.
Nashua, NH 03061
ATTN: D. White (1)

Sperry Rand Corp.
Sperry Gyroscope Div.
Marcus Ave.
Great Neck, NY 11020
ATTN: M/S D-18, G. Rand (1)

Standard Telephones & Cables Ltd.
Hydrospace Operations
591 Camino De La Reina
San Diego, CA 92108
ATTN: Jerry Miller (1)

Texas Research Institute, Inc.
5902 West Bee Caves Rd.
Austin, TX 78746
ATTN: Donald E. Glowe (1)

Tool-Tronics Hydrospace, Inc.
PO Box 1611
Zephyrhills, FL 33599
ATTN: John Clanton (1)

TRACOR, Inc.
Systems Technology Div.
1601 Research Blvd.
Rockville, MD 20850
ATTN: P.D. Flannery (1)
J. Guarnieri (1)
J.W. McClung (1)

TRW, Inc.
One Space Park
Redondo Beach, CA 90278
ATTN: A. Samsonov, Hd., Engr. Appl'ns. Sec. (1)

TRW, Inc.
7600 Colshire Dr.
McLean, VA 22102
ATTN: J. Mahler (1)

Vector Cable Co.
555 Industrial Rd.
Sugarland, TX 77478
ATTN: W. Savage (1)

Viking Industries, Inc.
21001 Nordhoff St.
Chatsworth, CA 91311
ATTN: Warren Buster (1)

Westinghouse Electric Corp.
Oceanic Div.
Box 1488
Annapolis, MD 21404
ATTN: C. Hikes (1)

University of Washington
Applied Physics Lab.
1013 NE 40th
Seattle, WA 98105
ATTN: Dr. C.J. Sandwith (1)

(BLANK)